Genetically Modified Crops, Science and the Precautionary Principle

By

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ABSTRACT.

The development of biotechnological solutions to previously insurmountable problems associated with agricultural production has led to the modification of the genomes of various crop species with genes taken from often quite different organisms. This technology is popularly known as genetic modification or GM. Opposition to the introduction of GM technology to mainstream agriculture has emanated primarily from environmental organisations, but has been strongly supported by groups and individuals with concerns about the biosafety of these crops or their possible effects on trade. In Australia, the States have used precautionary moratoriums to prevent the introduction of varieties that have been licensed for commercial production after scientific assessment by the Commonwealth's Office of the Gene Technology Regulator. This has led to a regulatory stalemate and the breakdown of the working relationship between the biotechnology sector and most of the States.

This thesis examines the rise of the concept of precaution as a response to the perceived inability of western democracies to satisfactorily deal with escalating risks associated with the rapid advancement of science and technology. It also considers the merits of science and precaution as influences in the GM regulatory system and the fundamental incompatibility of their basic ideas. The argument of the thesis is that a sound basis of scientific understanding is necessary to effective regulation and that precautionary approaches inhibit science. A research design involving the application of a comprehensive framework of outcomes to the cases of four GM crop plants is used to compare the effectiveness of precautionary GM regulation with that of science-based regulation.

The analysis shows that precaution, applied by the States since 2000 has been a less effective regulatory approach than the entirely science-based system

that previously operated. Precautionary regulation is associated with loss of industry competitiveness, diminished research capabilities, inferior environmental outcomes and the entrenchment of political discord. Science-based regulation has had positive outcomes in all these respects. The conclusion of this thesis is that while precautionary measures are capable of temporarily settling community concerns about biosafety, they cannot provide more than short-term regulatory solutions.

Chapter 1.

INTRODUCTION

The Issue

The banning of genetically modified (GM) canola by the major canola-growing States in Australia in recent years has raised the level of political tension between the economic needs of agriculture and the values of environmentalism to a critical point. In 2004, at the peak of the dispute, the Commonwealth - State relationship acquired a new and volatile edge when the Monsanto and Bayer corporations withdrew their programs for the commercial establishment of GM canola varieties in Australia. This action was a response to the decisions by the canola-growing States to maintain their moratoriums on GM canola after the Commonwealth Office of the Gene Technology Regulator (OGTR) had approved both corporations' varieties and commercially licensed them.

In 2006, as the ensuing deadlock between the biotechnology sector and the States persisted, the Commonwealth took steps to force a solution. In April 2006, the then Minister for Agriculture, Peter McGauran, announced a "comprehensive" $850,000 enquiry into "whether the crop [GM canola] should be introduced in Australia" ("The Weekend Australian", 29-30 April 2006). This enquiry consisted of eight separate "major" studies by the Bureau of Rural Sciences, the Australian Bureau of Agricultural and Resource

Economics (ABARE) and "the private sector" ("The Age", 29 April 2006), whose findings were publicly released over the following year or so[1] and added to the growing body of criticism of the moratoriums.

In May and July 2007, respectively, Victoria and NSW instigated fresh reviews of their moratoriums on GM canola. In late November 2007 both States announced that these moratoriums would not be renewed when they expired in early 2008. This meant that canola farmers would be free to begin sowing GM varieties in autumn 2008. Although some dissent was reported in the media at the time of the announcements and the major environmental organisations have consistently maintained their opposition to the use of GM canola, these decisions appear to have been generally accepted.

This significant adjustment of policy seems to have taken the immediate heat out of the issue but the underlying regulatory problems and political tensions remain. Unresolved differences over GM canola in the other States and Territories, and the incubating issue of GM poppies in Tasmania are in the front rank of foreseeable future disputes in Australia. In spite of almost total unanimity of scientific opinion on the question of the biosafety of GM canola, Western Australia, South Australia and Tasmania have strongly

[1] Such as ABARE's *Market Acceptance of GM Canola,* (Foster and French, 2007), which was released in March 2007.

reaffirmed their anti-GM stance, so political concessions by these States seem unlikely in the near future.

A further source of pressure is the many new GM varieties that are already in the research and development pipeline and which will undoubtedly refresh the debate in due course. Early settlement of the differences of policy and regulatory approach between Australia's governments is clearly desirable. Aside from the economic and administrative benefits that would follow the establishment of consistency and certainty, the entrenchment of friction within the community over this issue could ultimately lead to more pervasive and damaging consequences.

The Research Question

The political difficulty in Australia with respect to the regulation of GM crops arises from a conflict between the pressures for farmers to adopt GM technology, and fears about the biosafety of the technology within the community. Support for GM crops can be associated with traditional notions of progress and reliance on science, while opposition to them is linked to newer concerns with environmental integrity and the fallibility of science. These differences are mirrored in the incompatibility of the Commonwealth's broadly scientific approach and the States' broadly precautionary approach to GM regulation. Since precaution by its very existence challenges the ability of scientific analysis to adequately fulfil its informative role, the two approaches are not compatible and must be regarded as alternatives. This incompatibility raises a fundamental question, which is taken as the research question underlying this thesis: "Is GM crop regulation in Australia better[2] framed and implemented on the basis of precaution or scientific analysis?"

The GM Debate

The GM debate is centred on differences between mainstream proponents of scientific/rational assessment of GM varieties (who support the adoption of demonstrably safe technology) and dissenting GM opponents, who advocate the regulatory use of precaution to ban the technology on the grounds that its biosafety cannot be reliably predicted. Constructive argument has reached a stalemate over the irresolvable academic questions of certainty and the limitations of science. The epistemological point, that science is intrinsically uncertain can be construed to argue that the practice of science and the adoption of new technology inevitably involve serious and unacceptable risks (Kellow, 1999a: 65). This has led to risk become a consuming focus of attention in most spheres of human activity and at all social levels.

[2] The meaning and implications of the descriptor "better" are dealt with below in the section concerning hypotheses and also in Chapter 8.

Scholars such as Wildavsky, Adams, Formaini and Douglas[3], have argued that risk is inevitable and even necessary to social advancement, and risk management is now a major preoccupation of many decision-making organisations. The emphasis on risk as a cultural pivot and a parallel concern for the integrity of the environment have fed a natural tendency to distrust scientific and technological innovation, while a number of dramatic and large-scale failures and disasters have reinforced it. All this appears to have led to something of a lapse of public confidence in the direction that the science of the Enlightenment has been taking us, and consequently also to a re-examination of its principles and values. It is out of this reflective process that the idea of precaution has arisen. In the public's consciousness the practice of science and the use of new technology have now become linked to risk and danger.

The differences, at the extremities of debate, between environmental "precautionists" demanding iron clad safety via regulation and technological "adventurers" who dismiss periodic technological failure as the price of scientific advancement are reflected in the more serious ideas supporting their arguments. However, the tendency of directly applied theory and ideology to be pragmatically weak is exemplified by the shortcomings of

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[3] The arguments of these writers are discussed in Chapter 3. Wildavsky, Adams and Douglas have all been prolific writers on risk with numerous published works to their names. Formaini's *The Myth of Scientific Public Policy* was published in 1990. See reference section for more detail.

policies framed in accordance with their prescriptions. On the one hand, public fear of technology has grown out of allegedly excessive tolerance of risk and disregard for biosafety, while on the other, regulatory precaution has compounded the political difficulties and been accused of smothering innovation.

A further difficulty is that the central term "science" is often subjectively perceived and applied, so it has many intended meanings. Over the course of debate, particular confusion appears to have arisen over the distinction between the strict values and principles of traditional, peer-reviewed and openly accountable science, and the loosely defined "guidelines" of some (mostly notional) forms of unaccountable science. The intrusion into the areas of how science works (or should work) by social analysts - including some risk writers from both sides of the debate - with no genuine scientific learning or experience, is possibly responsible for the illogical persistence of the latter. As a consequence of this confusion, the debate about GM that is carried on is often futile, to the extent that it involves blurred or contradictory assumptions about the basic subject matter.

Theodore Lowi's important distinction between "mainstream" and "radical" politics (Lowi, 1987: x-xxi), which can explain the intractability of political conundrums such as GM, hinges on the recognition of a difference between rational and moral analytical bases. It is a development of the differences between induction and deduction, which in turn relate respectively to objective and subjective approaches to analysis. However, the characterisation of rational (or scientific) analysis itself as a radical or relativist process and the associated idea of the existence of alternative understandings of science undermine Lowi's position and tend to impede disinterested political resolution, along the lines of Lowi's own rationale. When reduced to its fundaments, the debate over GM amounts to no more than an argument over the irreconcilable merits of subjective and objective analysis of the issue.

Insofar as the practical politics of GM crop technology in Australia are concerned, the weakening of confidence in technology has led to the Commonwealth's (objective) science-based policy being successfully blocked at State level by (subjective) precautionary measures, predicated on the existence of scientifically improbable but hypothetically possible risks.

The Gene Technology Act and the Policy Principle

"Formal surveillance" of GM has existed in Australia since 1975 (Millis, 2001: 191), and prior to the existence of the Commonwealth *Gene Technology Act 2000* and the Gene Technology Regulator, it was sequentially the responsibility of several bodies, most importantly, from 1987, the Gene Manipulation Advisory Committee (GMAC). This organisation was comprised of :

> 19 members who are recruited from the scientific community and the general public ... selected for their expertise or knowledge. This ensures that GMAC

> has access to the most up to date knowledge of a wide range of organisms from persons who are active in research with studies at molecular level and, in the broader aspects of ecology, the environment and legal issues. (Millis, 2001: 191).

Millis, who was Chair of that body, has outlined the structure and operation of the regulatory system under it (Millis, 2001: 191-200). Although the office of Gene Technology Regulator and the Gene Technology, Technical Advisory Committee have since superseded this arrangement and apply the new Act and the Gene Technology Regulations, the Commonwealth process remains essentially the same (Millis, 2001; 191,200; DPIWE 2001: 17-18).

Under Section 27, Subsections *a* and *h* of the Commonwealth *Gene Technology Act 2000*, the Commonwealth Gene Technology Regulator, is currently required to make case by case determinations concerning licence applications for GMOs, essentially in relation to "risk assessment and biosafety", which is an ultimately a scientific and evidence-based undertaking. "Final approval" for food, drugs and chemicals is also scientific and is respectively the responsibility of Food Standards Australia and New Zealand, the Therapeutic Goods Administration and the Australian Pesticides and Veterinary Medicines Authority (McGrath, 2003, 32).

Under the provisions of Section 21 of the Act, however, the States are permitted to declare zones for "preserving the identity" of either GM or GM free crops "for marketing purposes". The Commonwealth is obliged to acknowledge the existence of State zone declarations in respect of the licences it issues, but it does not otherwise affect Commonwealth procedures or findings. This division of responsibilities reflects the ultimate reducibility of the various uncertainties attached to any GM variety down to two broad questions: Is it safe and is it better?

As a consequence of these arrangements both a Commonwealth licence and a State permit are necessary before cultivation, or other use, of a GM crop variety may occur. The regulatory process as defined by the Act thus involves two independently responsible and conceptually different regulatory systems. The Act, however, does not address the practical difficulties that this raises for the orderly regulation of GM crops and to make matters worse, does not specify the legislative intent or the evidential requirements of the marketing clause.

Experience has shown that these are almost fatally serious omissions as the States have been able and prepared to effectively nullify quite properly issued Commonwealth licences either by declaring whole States to be GM-free zones or by the imposition of serial moratoriums against particular crops. Predictably, this has provoked an angry response from the biotechnology and agriculture sectors. The primary focus of this activity so far has been GM canola varieties. Under the terms of the provisions of section 21, and in the context of bitter political debate, the commercialisation of GM canola has been entirely prevented for a number of years through precautionary bans (Meek, 2006, 2).

In May 2004, the future of the entire system was thrown into jeopardy when the Monsanto and Bayer corporations abandoned their GM canola trials in Australia. This was a very serious step that exposed the depth of economic risk that is attached to the use of precaution. On the 13th of May of that year, *The Sydney Morning Herald* reported Monsanto spokesman Mark Buckingham as saying that the company had "taken a business decision to suspend our investment [in GM canola] in 2004 based on the patchwork of different regulatory systems that we are faced with across the states".

Although the 2007 NSW and Victorian decisions suggest that a shift towards consistency in the regulatory system may be underway, fear of GM crops is now entrenched in some communities and, in the foreseeable future, even changes of government in the dissenting States may not lead to the abandonment of bans on GM technology.

Gene Technology Bans

Precaution has been formally articulated as the "Precautionary Principle", a concept that has currency in several versions. The most usually expressed form of the Precautionary Principle is Principle 15 of the 1992 Rio Declaration:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost effective measures to prevent environmental degradation (UN, 1992).

This version is incorporated into the Commonwealth *Gene Technology Act 2000* in Section 4, Paragraph (aa) as an element of the regulatory framework.

The logic underlying the Australian States' precautionary provisions may thus be understood to be that a putative biosafety risk attached to GM crops, involving the possibility of unspecified costs, can, if assumed to be significant, be extrapolated to insinuate a further possibility of damage to goodwill in the international marketplace. In plainer terms, the case of the States is that if they permit GM crops to be grown, fear of GM technology may cause their international customers to abandon trade with them, choosing in preference products originating in GM free zones. There was, however, little in the way of solid data to support this notion at the outset and the opportunity, provided by the moratoriums, to strengthen this case has not led to any significant change.

The Precautionary Principle has been strongly criticised (see, for example, Kellow, 2002: 124) for including a number of imprecise or ambiguous terms (such as "threats", "serious", "irreversible" "full scientific certainty") which demand subjective interpretation, thereby compromising it as a generally acceptable regulatory principle. While the environmental concern that the Precautionary Principle represents is genuinely and generally felt, the abandonment of scientific objectivity as an analytical essential at the political level is obviously profoundly problematic for some sections of the community and an insecure basis for policy.

The GM Record

The theoretical difficulties of the Precautionary Principle need not condemn it as a regulatory precept. A working, legal notion involving no obvious scientific or moral rule could conceivably be applied as a guiding principle if its implementation and effects complied with the practical demands of the law and reflected the needs of the community. This would, however, mean that there should exist a general acceptance of its validity and authority and that its application as an administrative rule should invariably (or almost invariably) yield optimum outcomes. These two ideas have an obvious relationship with the concept of broad cultural acceptance, referred to at the end of the introductory section.

As Table 1.1 below illustrates, the superficial regulatory record of genetically modified pharmaceuticals, food imports, processing aids, edible oil and crops indicates that neither of these conditions apply in the case of precaution. While regulatory outcomes have been consistently satisfactory when case by case scientific conclusions have prevailed and the logic of precaution has *not* been applied, they have typically raised problems of consistency and acceptability when scientific advice has been disregarded and precaution *has* been applied. This suggests that a closer study of the detail of GM crops and the ways in which they have been regulated, might reveal patterns of correlation between regulatory outcomes and regulatory approaches, particularly the Precautionary Principle.

Table 1.1

GM product, crop or Microorganism	Type of crop or product	Status & main likely determining factor	Influence of precaution
Cotton (NSW, Qld)	Industrial crop (edible by-products)	Legal since 1996 (economic/environmental benefits)	None
Poppies Tas)	Industrial crop (pharmaceutical)	No commercial crops, restricted trials. (Precaution)	Constrains Research. Bans crops
Canola (as a crop) (all States & territories except NSW, Vic, Qld)	Food crop (edible oil)	No commercial crops, restricted trials. (Precaution)	Limits research. Bans crops
Weevil-resistant Field pea	Food and fodder crop	Abandoned - health risk exposed during evaluation	None
Insulin	Therapeutic product (injectable)	Legal & available (health/economics/ no genetic content)	None
Modified *Lactobacillus* (still experimental)	Live bacterial HIV Blocking agent in dairyfood form	None. (Still under development)	Would probably be banned
Chymosin ("rennet")	Processing aid (enzyme)	Legal & available (present in imports/ no genetic content)	None
Cottonseed Oil	Edible oil	Legally used (cotton byproduct/ no genetic content)	None
Maize flour	Food ingredient	Legally used (present in imports)	None
Carnation	Industrial crop	Legally grown (small scale/non-food)	None

Summary, legal status and the influence of precaution on representative examples of GMOs in Australia as at January 2008. Compiled from numerous sources.

The Approach to Analysis.

If regulatory mechanisms are considered as devices with theoretical inputs (expressed as political intentions) and practical (or applied) outcomes, it is possible to view the GM regulatory system in one of two broad ways – either as the product of theory or as the generator of results. From an analytical perspective, this means that it may respectively be treated as either a dependent variable or an independent variable, so analysis of regulation can be either deductive or inductive.

Richard Simeon's seminal paper, "Studying Public Policy" (Simeon, 1976:549-550), makes a similar distinction, but Simeon saw significant academic value only in causal enquiry and not in outcome analysis, of which he was dismissive:

> It is even more important to rescue the study of policy from what we might call the technologists, whose main concern has been to develop aids to assist official decision-makers make in some sense "better decisions". In this view, exemplified by writers like Yehezkiel Dror, policy-making is essentially a technical question, a matter of developing more systematic means to canvass alternatives, assess costs and benefits, and implement choices. This literature, which appears to have had considerable influence with government decision-makers themselves, is also prescriptive: it seeks primarily not to *explain* how or why decisions are made, but to *prescribe* more effective ways of doing it. It also tends to focus its study narrowly, suggesting "better" policy – that is, policy which is more rational, consistent, cost-effective, and so on – will follow from reforms of administrative structure and development of new analytical techniques. Randall Ripley distinguishes between policy analysis – "advice on the choosing of alternatives" – and "policy theory" – "the explanation of why certain alternatives are chosen and others are not." If we are to understand politics generally, our study of policy must be firmly rooted in the latter view. (Simeon, 1976:549-550).

What Simeon does not consider here is that ultimately it is outcomes that matter to the public and to the economy and therefore to government. It seems unsurprising but significant that "government decision-makers themselves" should be interested in policy analysis. In a functional democratic system, feedback from political outcomes must eventually affect public policy and its processes, as well as perceptions of political theory. The point of studying public policy is surely to gauge its strengths and weaknesses with the intention of contributing towards the delivery of "better" or more advantageous policy. This certainly gives it direction and purpose, but does not mean it has to be narrowly prescriptive. Although it is possible that the particular body of literature Simeon refers to was exclusively prescriptive rather than explanatory, no logic confines policy analysis to prescription or precludes explanatory policy analysis. Convincing explanation and implicit prescription, on the contrary, seem inseparable.

Since the GM debate involves two adversative positions reflecting antagonistic ideologies and the political record demonstrates their incompatibility, a deductive solution (that is, theory as the independent variable and the regulatory process as the dependent variable) would be very unlikely to find general acceptance. The repeated failure of the Precautionary Principle - itself conceived as a compromising, deductive solution - to settle such matters, is evidence that insufficient common ground exists for sustainable agreement to be reached. One ideology and its political morality may ultimately become dominant, but presently this is not the case and in the absence of any other obvious alternative, it therefore seems futile to look to policy theory as the source of a potential solution to the GM problem.

This leaves the option of examining the pragmatic quality of regulatory outcomes (dependent variables) in order to determine the comparative usefulness of differing regulatory processes (independent variables). The changes to GM regulation along these lines afforded by the Commonwealth *Gene Technology Act 2000* provide a convenient means of doing this because this act marks the point of change at which the scientific standard was abandoned and precautionary regulation at State level became possible. Precautionary regulatory outcomes that have been reached since that point in time may be compared with conventional regulatory outcomes from before it by assessing each according to a small number of pertinent criteria.

A contemporary precedent for approaching the analysis in this way exists in the example of Aboriginal policy in Australia. In recent years, understanding of the difficulties and failures of Aboriginal policy over a very long period has undergone something of a revolution in response to a shift from deductive to inductive analysis of Aboriginal disadvantage. The past policies of segregation, assimilation, self-determination and reconciliation have all been associated with intractable health and general welfare problems. The emerging approach emphasises the identification of direct practical solutions to these problems in an ideologically neutral context and stresses national inclusiveness. These initiatives have had significant support from influential figures within the indigenous community[4].

From Research Question to Hypothesis

The intention of this thesis is to test the validity of a hypothesis framed to encompass the meaning of the research question: "Is GM crop regulation in Australia better framed and implemented on the basis of precaution or scientific analysis?" A direct, empirical answer to this question would be a product of the application of a measure of what is "better" regulation to all Australian GM crop regulatory cases. This is not a realistic proposal for two

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[4] Prominent Aboriginal lawyer and community leader, Noel Pearson, a strong advocate of the new, pragmatic approach, wrote in 2002:

> Federal Labor is dominated by what I call the progressivist, intellectual middle stratum. They have played a role in achieving recognition of Aboriginal property rights, but the prejudice, social theories and thinking habits of left-leaning, liberally minded people make them unable to do anything further for Aboriginal people by attacking our real disadvantage factors.
>
> The only answer to the epidemics of substance abuse that devastate our communities is organised intolerance of abusive behaviour. The late Professor Nils Bejerot pointed out that historically, substance abuse epidemics have been successfully cured without much in the way of research and voluntary rehabilitation. …I contend that the two most important factors maintaining and worsening Aboriginal disadvantage are the substance abuse epidemics and passive welfare. But these two factors ultimately depend on one single factor: the thinking of the progressive , liberally minded intellectual middle class (Pearson, 2002).

main reasons. First, the word *better* (or any appropriate substitute) reduces a complex assortment of objectively and subjectively assessed factors down to a simple, abstract idea that cannot be directly measured. Second, the total number of cases is far too high for them all to be considered in any useful detail.

However, better outcomes can very reasonably be equated with greater, long-term social advantage and, consequently, with social sustainability. It is thus possible to compare the sustainability of the current precautionary regulatory system of the States with that of the Commonwealth's scientific system, by rating representative examples of GM crop varieties according to a balanced selection of assessable indicators of social advantage.

A requirement for falsifiability and the avoidance of negative constructions are taken as principles that are logically essential to the composition of valid, working hypotheses. It follows from these understandings that if a comparison of any conclusive value is to be made, it is necessary to simultaneously test two mirroring hypotheses framed as objectively refutable propositions.

The two hypotheses to be tested, therefore, are:

> 1.The precautionary approach to GM crop regulation that has been applied by the Australian States under the Commonwealth Gene Technology Act 2000, is delivering outcomes that are measurably more advantageous to the Australian

community than those that arose from the previous science-based approach to regulation.

2. The science-based approach to GM crop regulation applied prior to the Commonwealth Gene Technology Act 2000, delivered measurably more advantageous outcomes to the Australian community than does the current precautionary approach of the Australian States.

Since the intention of the research is to test the strength of these hypotheses, the research process, consistent with the dictates of Popper[5], takes the form of "severe attempts to refute them" (Popper, 1972: 81). In practice, therefore, the purpose is to demonstrate that the available evidence does not, in either case, support the hypothesis.

The upholding of one hypothesis and the nullification of the other would

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[5] Popper wrote in his book *Objective Knowledge*: "The method of science is the method of bold conjectures and ingenious and severe attempts to refute them". He continued …

> … All we can do is search for the falsity content of our best theory. We do so by trying to refute our theory; that is, by trying to test it severely in the light of our objective knowledge and all our ingenuity. It is, of course, always possible that the theory may be false even if it passes all these tests; that is allowed for by our search for verisimilitude. But if it passes all these tests then we may have good reason to conjecture that our theory, which (we know) has a greater truth content than its predecessor, may have no greater falsity content. And if we fail to refute the new theory, especially in fields in which its predecessor has been refuted, then we can claim this as one of the objective reasons for the conjecture that the new theory is a better approximation to truth than the old theory (Popper, 1972: 81).

indicate that a clear conclusion could be drawn with respect to the relative merits of the approaches. Were both hypotheses to be either sustained or nullified, or if no clear result was obtained, it could be concluded that the comparative dimension of the exercise had failed to distinguish between the two approaches and that no important difference of outcome had been detected.

Two case studies from each type of regulatory regime will be considered. The examples of conventional (science-based) regulation are GM cotton and GM carnation. The examples of precautionary regulation are GM canola and GM poppies. These cases comprise:

1. Two GM crops that have been regulated on the basis of their scientifically established qualities (cotton & carnation).
2. Two GM crops that have been regulated on the basis of precaution (canola & poppies).
3. Two edible oilseed crops (cotton & canola).
4. Two "industrial" or non-food crops (poppies and carnations).
5. Two major international commodity crops (cotton & canola).
6. Two minor, localized crops (carnation & poppies).

GM cotton and GM carnation (both in several variant forms) are the only two GM crops that were fully licensed for commercial production under the GMAC system and so compulsorily comprise the two examples of scientifically assessed crops. They both, nonetheless, make excellent case studies, due to the very strong contrasts between the ways they are cultivated and utilised and their long records of use.

Canola, which is significant as the primary focus of controversy and as an economically important crop, also has some useful parallels with cotton. They are both widely grown, broadacre crops yielding edible oil and GM canola is technologically very similar to GM herbicide resistant cotton.

Opium poppies, which are grown only in Tasmania, are of particular relevance as they constitute a potential pressure point for GM advocates. They are of considerable economic importance in Tasmania and genetic modification is seen by the industry as inevitable. Poppies have been successfully modified and trial crops of GM varieties have been grown. GM poppies are also argued to be a fairly safe GM crop from a marketing perspective. As poppies are a source of narcotics, their cultivation is rigidly regulated and controlled, and since they comprise an industrial crop, issues associated with direct human consumption of the plant or its parts are avoided. It is consequently difficult to link the nature of poppy crops to the biosafety of food exports.

The analytical framework, or the specific criteria against which the four case studies are to be tested, will be drawn from the set of issues thrown up by the theoretical review and analysis that comprises the first half of the thesis.

Parameters

The scope of a PhD research project is particularly constrained by the limited human and material resources available. Ultimately, it is an individual endeavour that is reliant upon the capabilities of one person operating largely alone. This means that time also becomes an important restraint, so the boundaries of its realistic reach have to be acknowledged. If the argument made is to be concisely and economically communicated, it is necessary to disregard topics and areas of investigation that have potential significance, but which, for practical reasons, cannot be properly researched.

In this case, the many relevant international factors and events, although often considered informally as background material, are not included as part of the study. Moral considerations have been similarly treated. The very important areas of GM law and agricultural economics, while sometimes touched upon in a general way, are examples of relevant aspects of the issue that have not been comprehensively investigated.

The opinions and knowledge of a range of specialists have been sought, but the list of those consulted is necessarily limited. Although the narrow purposes of the investigation have been served, the views of political organisations, primary industry representative bodies, constitutional lawyers and trade experts are examples of possibly important avenues of inquiry that have largely been passed over. The consequence of these limitations is that the conclusion that has been drawn, although confidently argued on the basis of the available evidence, is ultimately qualified and would not be claimed to lie any closer to certainty than favourable probability.

Research

Research was conducted in three distinct and consecutive parts. The first involved a coverage of risk literature and other information sources, in order explore the background of the issue and gain sufficient understanding of it to develop an analytical purpose and an analytical framework.

The second part of the project was the gathering of data. This took the form of a desktop search for information from open sources and eighteen interviews[6] that were conducted with key informants in accordance with the

[6] The subjects were: Adam Kay, General Manager of Cotton Seed Distributors, Wee Waa, NSW; Ben Stephens (Farm Manager) and Tom Breen (Agronomist) of Auscott, Narrabri, NSW; Gary Fitt (Deputy Chief Entomologist) and Peter Reid (Research Scientist and Program Leader) of CSIRO; Cindy Hanson, Senior Policy Analyst, Tasmanian Dept. Primary Industry and Water; Malcolm McKenzie, grain farmer, Wagga Wagga, NSW; Peter Whitehouse (Breeding and Product Development Manager) and Scott Carpenter (Program Manager, Biotechnology) of the Bayer Corporation; Robert Sward, Manager, Biotechnology Policy, Dept. Primary Industry, Victoria; Bruce Finney, Executive Director Cotton Research and Development Corporation; Bronwyn Dixon, Senior Food Scientist, Food Standards, Australia and New Zealand, Canberra, ACT; Elizabeth Flynn, Director, Policy and Compliance Branch, Office of the Gene Technology Regulator, Canberra, ACT; Buzz Green, founder and Chief Executive, Serv-Ag, Devonport, Tas; Greg Hall MLC (Tas); Jeremy Rockliff, MHA (Tas) and Tony Fist, Manager of Agricultural Research, Tasmanian

applicable guidelines[7]. The choice of interviewees reflects the main purposes of the research, which were to investigate the science behind the selected crops, to ascertain its impact on regulatory processes and to establish the consequences of the two regulatory approaches to GM technology. The intent was not to investigate or record public political debate. The semi-structured, face to face interviews involved five or six previously forwarded questions and typically lasted between thirty and sixty minutes. The material obtained was transcribed, checked by the source and summarised. One interview (with Gary Fitt of CSIRO) was conducted by telephone, with the same follow up procedure, while Stephen Ainsworth of Monsanto and (for his second interview only) Tony Fist of Tasmanian Alkaloids provided written answers to written questions by email.

Data collected in this way can provide a valuable supplement to open source material by accessing information that is specifically relevant to the research. It is also, in some instances, a means of directly accessing obscure or privileged information, or the insights and experiences peculiar to an individual or a position. The main disadvantages are the time and difficulties involved and the issues of reliability arising from the inherent subjectivity of the process.

Alkaloids . Two of these (Ben Stephens of Auscott and Greg Hall MLC) declined to have their comments formally recorded and have consequently not been cited.

[7] That is, according to those set down by the Southern Social Science Ethics Committee.

The third task was analysis of the material gathered and the development of conclusions. The analytical process involved testing or assessing the regulatory outcomes relating to each of the crops in respect of four types of criteria: "Direct-Physical", "Economic-Material", "Conceptual-Research" and "Social-Political". The logic of these choices and the meanings attached to them are explained in Chapter 5, but they substantially fulfil the requirement that variables be mutually exclusive and exhaustive.

Outline and Synopsis of Thesis

This thesis is a product of the existence of differences of intent and understanding between the State and Commonwealth arms of the GM regulatory systems in Australia, which in turn stem from incompatible views within the Australian community. These differences have led to the failure of the system as a whole to deliver generally acceptable regulatory outcomes.

It is a premise of this thesis that rational analysis based in empiricism can identify patterns and inconsistencies in the record of events and facts, thereby leading to the possibility that the regulatory intentions of the States might be reconciled with those of the Commonwealth. The conclusion reached is that precautionary regulation of GM crops has led to indecision and uncertainty, so that the long continuation of this approach would be likely to threaten the economic health of the agriculture sector in Australia. Properly conducted scientific evaluation, although not entirely free of risk can be shown to be a safer basis for decisions. It has, so far, consistently provided informed and reliable guidance on these matters.

The work has two main parts. The first of these, consisting of Chapters 1 to 3, is concerned with the theoretical background to the issue and the thesis, while Chapters 4 to 9 comprise the original research and its findings. Some aspects of the idea of risk are analysed in the second chapter[8], which critically considers the arguments of several eminent and representative scholars of the subject who have significantly influenced the way in which it has been understood and managed in recent years. The positions of John Adams, Aaron Wildavsky, Robert Formaini and Mary Douglas are examined in some detail in preference to the alternative approach of more superficially reviewing the work of a broader selection of writers.

Despite the significance and the pertinence of many of the observations and arguments of these thinkers, it is within the context of their guidance on the topic of risk that the difficulties of risk management that comprise the subject matter of this investigation have arisen. Their concessions on the questions of subjectivity and the function of science have provided leverage points for the case against empiricism and scientific analysis that underpins the concept of precaution. This chapter, therefore, actively seeks to uncover problems and

[8] Chapters 2 and 3 could have been presented in reverse order. The existing sequence was judged most logical but neither option is entirely satisfactory.

incongruities in their arguments in an attempt to establish a consistent and coherent intellectual standpoint on the subject as the conceptual basis of this thesis.

Chapter 3 considers the emergence of the Precautionary Principle as a political idea and looks to its conceptual limitations for explanation of its failure to satisfactorily resolve the regulatory problem of GM technology and risk. This chapter establishes the context in which it arose, examines its possible meanings and identifies shortcomings.

Chapters 4, 5, 6 and 7 present the case studies of the four GM crops being studied - cotton, canola, carnation and poppy. The intention is to provide a sound basic understanding of each as a part of the economic and agricultural fabric of Australia. Analysis of the cases is undertaken in Chapter 8. Various outcomes of the regulatory management of the four GM crops selected as case studies are compared, in order to throw light on the differences of outcome between scientific and precautionary regulation. The final chapter presents the conclusions of the thesis and considers some significant questions that have been raised by the research process, but which remain unanswered.

Chapter 2.
RISK THEORISTS

The introductory section of this thesis has argued that politicisation of theoretical inconclusiveness surrounding science and biotechnology has translated into difficulties of a practical and economic nature for the agricultural sector in Australia. Debate about science, uncertainty, probability and technological failure is now frequently categorised under the broader heading of "risk" and the mainstream theorists Mary Douglas, Aaron Wildavsky, John Adams and Robert Formaini are among the more significant scholars of this subject whose work has collectively influenced public policy over a generation. The evolution and increasing acceptance of the essentially anti-scientific concept of precaution over the same time – roughly the period since the Vietnam era – can hardly be a coincidental development, so it is in the understandings of these writers on risk that incongruity and theoretical difficulties should logically be sought. Definition of the terms upon which science is accepted and a clear expression of its function are preconditions for lucid discussion of this subject matter, particularly in circumstances of epistemological flux. This chapter seeks to identify the difficulties in order to clarify, for the purposes of this thesis, the task and nature of science, and to thus also provide firmer grounds for the evaluation of precautionary thought and the Precautionary Principle in Chapter 3. It explores the contributions of the above-mentioned theorists to the understanding of the concept of risk, commencing with the work of John Adams and then, in turn, that of Aaron Wildavsky, Robert Formaini and Mary Douglas.

John Adams

John Adams is an influential contributor to the debate and literature of risk. He has strongly challenged the mathematical understanding of risk as a measurable entity, which he sees as narrow in its logic and tyrannical in its implementation. His writing suggests a deep concern with authority and its expression as callous, bureaucratic officiousness. The "tyranny" of majorities over minorities and a tendency towards the establishment of "despotic" elites have both been well established as practical shortcomings of democracy, and Adams is a spirited defender of individual autonomy and vulnerable minorities.

At its most simple, the observation underpinning Adams' position is that risk perception is reflexive and self-regulating. Behaviour in circumstances of perceived risk is altered in order to accommodate that perception, thus reducing or raising the actual level of risk. Accordingly, the imposition by authorities of safety measures intended to reduce danger serves to change or displace risk perception so the *real* danger level tends to return to its original level as people take greater risks in the context of greater safety. He refers to this phenomenon as "risk compensation". In the preface to his book "Risk" (first published in 1995), Adams writes that risk compensation theory:

> accords primacy in the explanation of accidents to the human propensity to take risks. The theory postulates that we all come equipped with "risk thermostats" and suggests that safety interventions that do not affect the setting of the thermostat are likely to be frustrated by behavioural responses that reassert the level of risk with which people were originally content. (Adams, 1998: ix).

The second understanding central to Adams' thesis is that people perceive and manage risk according to four worldviews. This results from his linking the idea of risk compensation to the "perspective that has come to be known as 'cultural theory' developed by Michael Thompson" (Adams, 1998: ix), which views risk as:

> culturally constructed; where scientific fact falls short of certainty we are guided by assumption, inference and belief. In such circumstances the deterministic rationality of classical physics is replaced by a set of conditional, probabilistic rationalities. ... Cultural theory illuminates a world of plural rationalities; it discerns order and pattern in risk-taking behaviour and the beliefs that underpin it. Wherever debates are prolonged and unresolved ... cultural theory seeks an explanation not in further scientific analysis, but in the differences in premises from which the participants are arguing. (Adams, 1998: ix).

Adams' position, then, is ultimately a relativist one that perceives and emphasises an essential equality between different "rationalities" and views risk as being ubiquitous and, critically, very human. Scientific measurement and analysis is accordingly seen as a simplistic, narrow and limited approach to dealing with risk and in his estimation it signifies "very little" (Adams, 1998: 3-4). This rejection of the prevailing objective or scientific approach to risk constitutes the third important element of Adams' thinking and is dealt with in some detail in the second half of "Risk".

Adams cites chaos theory as the basis for his further assertion that "complex natural systems" are "inherently unpredictable" due to their "extreme sensitivity" (Adams, 1998: 4). His rejection of the validity of empiricism is almost absolute. "Rarely" he says, "are risk decisions made with information that can be reduced to quantifiable probabilities" (Adams, 1998: 4). Consequently, Adams divides the world (more or less along an objective/subjective fault-line) into two camps with respect to the perception of the meaning of risk. These are a "formal sector" closely linked to authority, that pursues the objective of risk reduction and an "informal sector" consisting of ordinary human individuals whose objective "is to balance risks and rewards" (Adams, 1998: 4). These sectors "co-exist uncomfortably", with the behaviour of the informal sector "modified by the activities of the formal sector" (Adams, 1998: 4-5).

The "theory of risk compensation" fundamentally underpinning Adams' argument was originally devised by Gerald Wilde in 1976 but has been modified significantly by Adams over the intervening years (Adams, 1998: 14). It hypothesises that all individuals have a unique propensity to take risks which involves weighing potential rewards against potential losses and that rewards and losses will be incurred in proportion to the risks taken (Adams, 1998: 14-15). Adams considers that the propensity to take risks is reflective of a "need for excitement inherent in all of us … a need for a certain level of arousal" (Adams, 1998: 15). This perception leads to his assertion that "the starting point of any theory of risk must be that everyone willingly takes risks" (Adams, 1998: 16)

Building on this premise, Adams considers the idea drawn from quantum physics that uncertainty is "inherent in physical nature" (Adams, 1998: 17) and the opinion, expressed by quantum physicist Max Born, that it "is the only thing that permits us the possibility of moral significance [through the exercise of] … responsibility and conscience. Without it", says Adams, "we are mere predetermined automata" (Adams, 1998: 18). He goes on to cite Dostoyevsky's rationale that there exists an essential, human determination to maintain a capacity for independent choice which is critical to the existence of individuality and consequently also of personality. As a result, "the greater the success of the safety regulators in removing uncertainty from our lives, the stronger will become the compulsion to reinstate it" (Adams, 1998: 19). Thus risk compensation theory postulates the presence of a fundamental human resistance to the development of entirely risk-free environments and that a risk-free world "would be one with no uncertainty or freedom or individuality" (Adams, 1998: 19).

Adams became interested in cultural theory because he believed it "would cast helpful light on how the [risk] thermostat was set" (Adams, 1998: ix). Founded on Douglas' and Wildavsky's view, expressed in their book "Risk and Culture" (1990), that risk is "culturally constructed" (Adams, 1998: 35), the Adams version of risk construction embodies Holling's idea that cultural assumptions about nature can be reduced to three groups (Adams, 1998: 33) and Schwarz's and Thompson's further development of these "cultural patterns" into a "fourfold typology" (Adams, 1998: 35). The combination of these ideas forms "the central framework of Cultural theory" (Adams, 1998: 38).

Adams graphically locates the four types of understanding on a bivariate chart with two axes representing variations between individualised and collectivised outlooks (x axis) and social environments of equality and inequality (y axis) (Adams, 1998: 35). The described types are: individualists (bold, entrepreneur-types who regard nature as robust and well-buffered), egalitarians (more cautious types who regard nature as fragile and delicately balanced), hierarchists (conservatives who regard nature as having reasonable but limited robustness) and fatalists (resigned types who regard nature as unpredictable) (Adams, 1998: 34-36).

These notions are perceived to be representative of "four distinctive world views [reflecting] four different rationalities" the different underlying premises of which are "themselves beyond the reach of rationality" (Adams, 1998: 37). This effectively means that they are intrinsically beyond analysis and (given the distinctions between them that are emphasised by their placement at the four extremes of the graphical axes) also rationally incompatible. Adams further stresses the cultural basis of these rationalities by pointing out the means by which they are maintained:

> Both the paradigms of science and the myths of cultural theory are powerful filters through which the world is perceived, and they are reinforced by the company one keeps. (Adams, 1998: 37).

While noting that "empirical support for the theory ... is sparse", Adams suggests that "in the uncertain world we inhabit" its validity is to be judged by "the degree to which it accords with people's experience" (Adams, 1998: 38). He uses the very relevant example of traffic pollution to illustrate this point and to expand his main argument (Adams, 1998: 38-45), which he applies to "all disputes that are unresolved or unresolvable by science" (Adams, 1998: 45).

A 1983 US National Research Council report is cited by Adams as providing evidence to support his belief that science is "groping in the dark" (Adams, 1998: 49). Scientific ignorance about the potential of almost all of the "5 million chemical substances ... known to exist" to negatively affect human health, and an alleged inability of science to assess them accurately anyway (Adams, 1998: 45-50) are used to buttress this argument. The section concludes:

> The prospect of future research breakthrough lighting more than a few flickering candles in the vast darkness enveloping the problems they are addressing is not encouraging. Indeed the problem appears to be getting worse as the rate continues to increase at which chemists, physicists and genetic engineers create new dangers. Even more urgent than the need for more science is a need for a better understanding of the bridge of inference and belief. (Adams, 1998: 50).

Critical Assessment of Adams' Position

The observation of a link between risk perception and compensatory behaviour is at once both facile and profound. It is obvious that people modify their behaviour in response to perceived danger, but we do not so readily recognise that when we consciously or deliberately modify risks we are also affecting likely behavioural responses. The consequence is, as Adams has pointed out, that safety measures may have the effect of altering the degree, nature or location of a particular risk. This realisation has important implications for the decisions and practices of governments and government bodies at all levels, adding a highly significant dimension to questions of risk. Its logic is clear and Adams has convincingly argued, with numerous examples, (such as Adams, 1998: 113, 125-126, 154-155) that planned safety measures can result in unforeseen and undesirable outcomes for this reason.

However, the broad acceptance of Adams' principle as a vehicle for achieving a greater common good ultimately means the permanent acceptance of a certain level of risk and consequently also of accidental deaths, injuries and material losses. Indeed, taken as an absolute, risk compensation implies that imposed safety measures are pointless because they can never make any difference anyway. Neither of these propositions though would be attractive to political institutions sensitive to popular feeling or to community members and leaders, who would consider any such position to signify resignation and failure. Adams' own experience with government seems to confirm this.

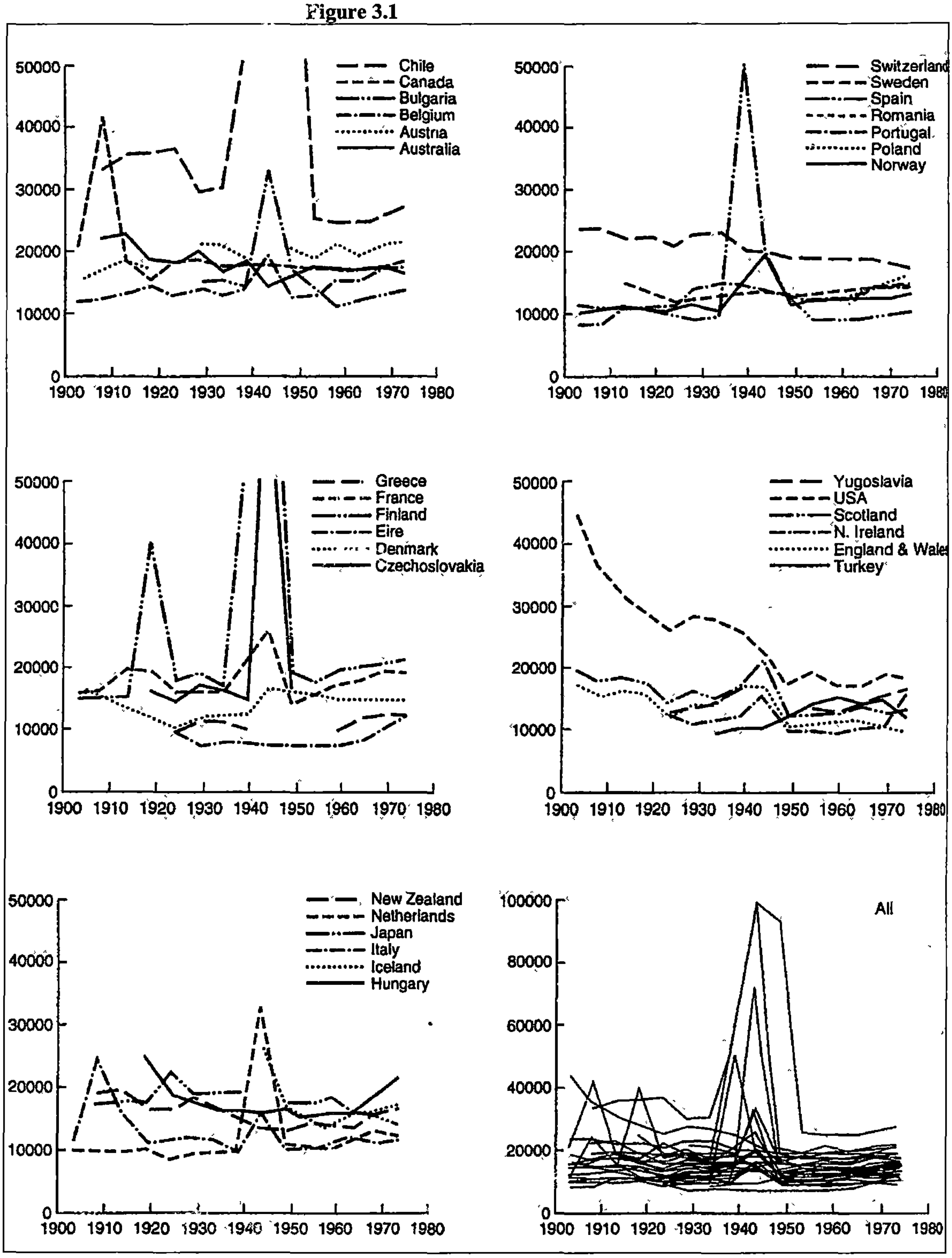
The extension of risk compensation into risk compensation theory is not as well argued, being less well supported by both evidence and logic. The use of cultural theory to justify risk compensation theory, also without the support of persuasive hard evidence, does little to overcome the problem. The further attempt by Adams to take a hatchet to empiricism in general and its application to risk in particular, is necessary to support these theoretical extensions. Although he exposes much irrationality, narrow thinking and bureaucratic arrogance in the process, and weakens significantly the case for certain empirical approaches to risk management, his attack on scientific thinking is not strongly supported by the evidence he offers and is ultimately unsuccessful. These points will each be further discussed in a little detail.

Risk Compensation Theory

Adams progression from the observation of risk compensation to risk compensation theory is based upon the observation that "everyone has a propensity to take risks" (Adams, 1998: 14,16) and involves the notion of a risk thermostat (Adams, 1998: ix). The idea that risk-taking is essential to human nature is perhaps difficult to demonstrate. Certainly risk-taking is inseparable from living and is necessary for life to continue and all people probably enjoy risk-taking at some level. However, neither the enjoyment of risks, nor the fact that people routinely take them can be argued to show that people innately and involuntarily maintain a set level of risk in their lives.

The strongest empirical evidence that Adams offers in support of risk compensation theory is the six graphs reproduced in Figure 3.1 overleaf which illustrate "ratios" of death by accident and violence in thirty one countries over the first three quarters of the Twentieth Century. Although they are described as "standardised mortality ratios", (Adams, 1998: 60) their axes are unlabelled, so the values represented on the "y" axis and by the curves unfortunately remain unknown. Nonetheless, their patterns are clear and a general tendency towards maintenance of a steady level of deaths over long periods is discernible. This characteristic is visually accentuated by the smaller vertical scale of the last, aggregate graph that has the effect of vertically compacting the data on the graph. Adams is quite properly cautious about the strength of the claims he makes on the basis of this statistical record, but he observes that "risk appears to have been suppressed in some activities only to pop up in others" and suggests that:

Figure 3.1



Deaths by accident and violence for 31 countries, 1900 to 1975.
Source: Adams, 1998: 60.

> there is little to show in the aggregated statistics of death by accident and violence for all the labours of the risk reducers – the regulators, the police, the doctors, the safety engineers and all the others involved in the safety industry over many decades. (Adams, 1998: 61-62).

Quite clearly, Adams is saying, the efforts of the "risk reducers" to reduce the costs of risk has transferred rather than eliminated them.

However, this interpretation implies that new activities involving risk are merely the product of risk reduction measures. It ignores the restless, inquiring nature of the human mind and the constantly changing and evolving pattern of human activity that this engenders. Assuming (as Adams quite reasonably does) that the specific causes of these deaths do change over time, the graphs convey no more information than that an ongoing equilibrium appears to exist between the rates at which old problems are solved and at which new problems are encountered. They do not distinguish between causes of death and hence cannot illustrate the existence (or the absence) of any relationship (causal or casual) between deaths from one cause and those from another.

Adams applies risk compensation theory to conventional approaches to road safety at some length (Adams, 1998: chapters 7& 8) offering statistical evidence to support his claim that the approach is essentially wrongheaded and counterproductive. While convincingly arguing that the phenomenon of risk compensation ought to be included in the assessments and decisions of road safety, most of his empirical evidence does not isolate the factors under question and so cannot demonstrate the causal relationships he seeks to show (such as Adams, 1998 127, 138-140). What they do effectively demonstrate above all is the bottom line of the available hard evidence - that road fatalities are falling in the face of huge increases in vehicle registrations and road use. According to risk compensation theory this cannot happen as a consequence of safety measures unless deaths from other risk-related causes increase in response.

Total road fatalities in Australia have approximately halved since 1970, falling from 3,798 to 1,636 in 2005, while fatalities per 100,000 persons fell from 30.4 to 8.1 and fatalities per 10,000 registered vehicles fell from 8.0 to 1.2. over the same period (ABS, 2007). During this time, car registrations, population and car ownership all increased significantly and a continuing road safety campaign has been waged, involving the imposition of increasing constraints on driving behaviour. No doubt, over the same period, accidental deaths from other causes such as recreational drug use and high risk sports has simultaneously increased, but there is no good reason to logically link these things and use risk compensation theory to explain increased drug overdoses. It is conceivable that road safety campaigns which dissuade young men from taking risks on the roads result in more hang-gliding and substance abuse, but a patterned relationship between these things is not intuitively obvious.

There is though a clear causative relationship between road safety measures taken in Australia in the last thirty-five years and steep falls in fatal accident rates, which does not support risk compensation theory. Adams' assertion that "as traffic increases, the death toll is contained, and sometimes reduced, by behaviour that avoids danger rather than removing it"(Adams, 1998: 140) is credible but not verified by his evidence. It is equally *in*credible that road safety measures would have no net effect upon the road toll. In any case, the halving of the road toll over thirty five years is well beyond his claim of containment.

Adams' previously mentioned graphs (Figure 4.3 Adams, 1998: 60) do show, reasonably convincingly, that deaths by violence and accident remain at a roughly constant level in various populations over long periods of time, but they do not explain this. The constant level does suggest the existence of a governing link between the reductions and the increases in deaths from different causes, but it is not possible to conclude from the information presented (and Adams does not) that it validates risk compensation theory. It is possible, though, as Adams does, to view this material as strongly supportive of the theory.

On the other hand, these graphs (and much of Adams' other evidence) are equally supportive of a possibly more credible counter-logic which is also compatible with the phenomenon of risk compensation. This logic is that, contrary to Adams' proposition that humans perversely insist upon maintaining a fixed (or minimum) level of risk and death in the face of broadly supported efforts to reduce them, they are prepared to tolerate deaths by violence and accident only up to a common *maximum* level. The corollary of this is that social acceptance of risks resulting from human imagination and scientific inquiry, such as technological advancement, may be understood to be *limited* by the rate at which safety measures for existing technologies are devised and imposed. This is contrary to the implied logic of risk compensation theory that such acceptance is conditionally dependent upon a social reaction against risk minimisation. Accordingly, the acceptance of novelty and invention, with their inherent risks, could be considered to be conditionally dependent upon the satisfactory resolution of old problems and the elimination of existing risks.

The inevitable end point of this logic is that productive efforts to minimise existing risk-associated costs must increase the preparedness of communities and individuals to take up new challenges. For example, until a relatively recent change, heavy vehicles in Tasmania were limited to a maximum speed of eighty kilometres an hour. On the basis of a good safety record and technological advances, this was increased to a hundred kilometres an hour. Although an initial increase in the accident rate was a risk, it would have been possible to reduce maximum speeds until a low, acceptable, accident rate applied again. But the same transport system, with a high initial accident rate would have been expected to employ measures to reduce accidents, possibly including a reduction in its maximum operating speed below eighty kilometres an hour in order to achieve an acceptable level of safety. Increasing the maximum speed (the independent variable) would be unthinkable until the system was operating at an acceptable level of safety (the dependent variable). The rationale of risk compensation theory would be that the independent variable of the thermostatically set accident rate would determine the speed at which trucks should be driven.

The advantage of this conceptual position over risk compensation theory is that it is entirely consistent with the behaviour of governments, communities and individuals virtually everywhere who, quite reasonably, pragmatically and humanly, take great pains to minimise human and material loss before extending risk activity. This renders unnecessary an explanation for the problem of human perversity, provoked by compensation theory, which involves the simultaneous expression of essential social needs to both minimise the dangers inherent to risk while compensating for that minimisation with more dangerous behaviour. Thus the requirement for a social theory of cultural diversity to validate the primary corollary of risk compensation and accommodate its obvious difficulties is dispensed with. If empirical evidence is the evidence of experience, the clear existence in advanced democracies of a consistent and persistent, historical pattern of general concern at government level to reduce risk, provides strong empirical support for this alternative position. Denial of the validity of this evidence is denial of the essential understanding of democracy – that the activities of representative governments, in broad terms, reflect the wishes and aspirations of their electorates.

At several points in his narrative (such as Adams, 1998: 11,16,30,114), Adams chides governments and safety authorities for seeking a zero risk environment, but the pursuit of harm reduction, as a constituent of social betterment, seems a high cultural priority. Ever-increasing efficiency and technological sophistication are probably of equal rank on most socio-political agendas. Excepting authoritarian and violent regimes, it is hard to conceive of circumstances in which any responsible government would not actively seek risk-minimisation.

Of course, nobody likes accidents and Adams is not suggesting that they do or should. People abhor needless and expensive injury, death and loss and obviously want to enjoy life and health, so it is natural and reasonable for them to expect their governments to think in the same way. Communities do not, on the whole, desire or accept policies that will lead to accidents, losses or damage and governments must respond to their communities if they want to be re-elected. Certainty is vastly more attractive than uncertainty, so policies offering predictability and security will transfer into votes. Policies that involve the public's acceptance of losses or uncertainty are obviously unappealing to voters and so are eschewed by political parties. Risk compensation theory seems to unavoidably provoke a problem of logic with regard to human behaviour and to imply aspirational confusion and political dysfunction in the election and operation of democratic forms of government.

Cultural Theory

While Adams openly admits to vulnerability with respect to the demonstrable validity of Cultural theory (Adams, 1998: x; 38; 64; 66; 200), he says he still finds it "useful" (Adams, 1998: x). Nonetheless, it remains a problem for his argument that Cultural theory's four[1] "rationalities" of human nature[2], also referred to as "myths", (Figs 3.2 and 3.3, Adams, 1998: 35, 37) cannot be shown to be anything other than arbitrary values supported by circumstantial evidence.

Superficially and subjectively, the four "myths" provide a reasonable description of the main ways in which risk is perceived, but the absence of a strong empirical basis or other compelling logic jeopardises the credibility of any theoretical projection premised upon their validity. Although not an unreasonable proposition, cultural theory is vulnerable to the claim that it is no more than plausible conjecture. Ptolemy's view that the earth was the

[1] A fifth "way of life" (Adams, 1998: 200) described in the last chapter of Adams'book, is here ignored, as encompassing it would involve unnecessary and distracting complication of the argument.

[2] Hierarchists, egalitarians, individualists and fatalists.

centre of the universe no doubt seemed a reasonable supposition prior to its refutation by the hard empirical evidence of Copernicus.

A diversity of understandings of the world about us, including the understanding of risks in general and risks in particular, no doubt exists and Adams' construct provides, in some respects, compelling and valuable insights concerning this complexity. The possibility of multiple interpretations of any given set of information is easily forgotten or ignored and his model emphasises this possibility.

It also involves recognisable truths and so appears to fit the evidence of everyday life, tempting one to accept its logic. However, its value is limited. The four values of cultural theory are not shown to be, in any evidential sense, substantial or exhaustive of possible human understandings of nature or the universe or risk. These categories are strongly reductionist in nature, to the point of dangerous over-simplification. It would be no less rational, but equally misleading to classify and then draw major conclusions about Australians as humans according to the political party they last voted for, their ethnic background, religious convictions or their socio-economic status. Furthermore, the names these categories have been given are drawn from morally loaded values, which presume to comprehend and explain the primary motives of human behaviour. The more closely it is examined, the weaker the "cultural" thesis appears. Are hierarchists all in the government and do egalitarians, individualists and fatalists all vote for the hierarchists? If not, why and how is the hierarchist view of risk inflicted upon everybody else? Did the hierarchists alone develop hard science and somehow impose it upon the world? Does hard science rationally fit into the theory al all? The unanswerable questions are endless.

Adams openly recognises and acknowledges many of the weaknesses of cultural theory and attempts in the last chapter of the book to, at least partially, overcome them. He (apparently adopting ongoing modifications to cultural theory) adds a further dimension to the concept, which increases the number of possible human categories fourfold, to sixteen. This reduces the conspicuousness of the substantiation difficulty, but does not remove it. Indeed, he openly admits to the failure of efforts to statistically verify the theory (Adams 1998: 38; 200). Nevertheless, its function in Adams' argument is critical, as has been noted. Its role is to neutralise the logical tension between the vital premise that people and communities inevitably assert their need to take risk and the glaring difficulty provoked by the measurable fact that large portions of the resources of most advanced societies around the globe are devoted to eliminating risk.

Cultural theory's apparent conjecture is that a culturally based, internal, structural conflict is responsible for this anomaly. The complex struggles between the forces for risk-taking and the forces for risk-reduction are presumably alleged to give credence to the notion that essential risk-taking and risk-minimisation social dynamics are not rationally or practically irreconcilable. If the assumptions and claims of cultural theory or a suitable substitute are denied, risk compensation theory remains exposed to the assertion that it flies in the face of overwhelming and obvious evidence that individuals and communities emotionally and rationally aspire to eliminate risk.

While noting that "empirical support for the theory … is sparse", Adams asserts that "in the uncertain world we inhabit", its validity is to be judged by "the degree to which it accords with people's experience" (Adams, 1998: 38). However, empirical evidence *is* experience and scientific empiricism is nothing more or less than formalised guidelines for the re-creation and measurement of experiences under conditions that strive to minimise the opportunities for error due to subjectivity or other distortions. The substitution of opinion for unavailable evidence marks the point of the abandonment of analytical reason.

Martin Landau (1972: 7-13) was a noted critic of the tendency to discount the value of scientific quantification:

> There is no human judgement that is not based upon "sampling": any observation, of any kind, is a count, and any conclusion must be based on a sample survey … If Morgaenthau and Wolin have concluded that quantification has trivialised our work, have they not assigned a "grade"? There must be a scale involved in this judgment, probably unidimensional,

> ranging from trivia to importance – and by some count of some sample, they have plotted the quantifiers on this scale.

As Landau implies, the abandonment of analytical discipline risks mental drift towards recognition of only desirable information and rejection of the undesirable. It is simply not good enough to trust subjective human judgment to be the arbiter of the validity of cultural theory. To dub cultural theory "the anthropologists' myth of myths" or a "super-myth" as Adams does (Adams, 1998: 38) is quite acceptable, but it is not acceptable to then declare that it has greater validity than empiricism and that this validity can only be verified by recourse to other myths. Although a side issue, it is also the case that the possibility of the existence of validity requires the existence of absolutes, which Adams appears to deny. Both of these understandings are fundamental to the concept of empiricism.

The Problems of Empiricism

Absolutes and certainty may or may not exist in the universe, meaning that ultimately empiricism and hard science may well not be the most appropriate possible instruments of material interpretation. But the ultimate truth about these things is largely irrelevant here, the pertinent understanding being the way in which humans comprehend and communicate about their physical environment. People perceive the world in what might be termed a practical way, meaning their perceptions are related to their own sensory experiences and are based upon a *relative* certainty about its nature. This is the certainty historically constructed upon a common human understanding of the world as it is thus perceived through the senses. It is not possible to form or communicate meaningful ideas about the material world without reference to what people agree to be meaningful evidence. This is what is commonly called "truth". The general belief in the material existence about us and the way it behaves allows us all to agree that fire is hot, water quenches thirst and concrete is hard. Denial of such things (which are also called "facts") falls outside the bounds of our common practical experience and so cannot be considered useful in communicating with other humans generally. Consequently, it is not possible to make broadly coherent statements about the world without reference to such truths, or to accounts that are understood to be truths. The awareness that cultural and personal understanding may conflict with these commonly agreed truths is logically the basis of the formality of scientific analysis, which merely seeks to establish and describe the nature of material entities in terms that are universally acceptable.

A simple model of human understanding of a particular thing may, on this basis, be considered to consist of areas of empirical certainty and areas of empirical uncertainty. To achieve a confident working understanding of it, areas of empirical uncertainty need to be either empirically understood or to be transformed into a form of certainty by constructing it through cultural or personal understanding. Hard science may be understood to formalise the processes of empirical enquiry in order to exclude the empirically uncertain and to construct platforms of certainty by linking many empirically established facts upon which theory may be built. The technology upon which much in modern life depends, such as medicine, communications, transport and food production are completely the product of this kind of thought.

A basic problem for Adams is the ambiguity surrounding his articulation of his understanding of such fundaments. This ambiguity is expressed in two main ways. Firstly, he rather sweepingly dismisses those who accept the scientific notions of empiricism and relative certainty as "Kelvinists, in keeping with the theological character of their position" (Adams 1998: 10-27), yet he does not hesitate to point, again and again, to empirical evidence as the proof validating his assertions. Secondly, since cultural theory is a relativist construct, premised upon the non-existence of absolute truths or any form of certainty, and the equality of the merits of competing world-views, empirical science can presumably only be considered to be another competing interpretation of the world. Yet Adams does not take the step of either embracing this view or otherwise clarifying the dilemma it creates for the acceptability of the evidence he offers. He allows empirical science to drift from positions of validity to positions of non-validity (such as Adams, 1998: 77 and 10) as occasion demands. It is not at all clear where he can locate it in the difficult presence of cultural theory as the following example shows.

With reference to the application of the four "rationalities" of cultural theory to the example of traffic pollution (Adams, 1998: 38-45), Adams states that his "speculations" are "relevant to all disputes that are unresolved or unresolvable by science" (Adams, 1998: 45). Ignoring the possibly pedantic point that speculation is definitionally not relevant to anything, the logic of this statement involves an unstated presupposition that another, truly objective and analytically superior rationality - science - actually exists, in spite of his frequent statements to the contrary. Given the primacy of opportunity to resolve disputes, which he here accords to science, it can only be construed that the other four "rationalities" are applicable only in the absence of sound scientific evidence. In other words, the implication is that certainty ultimately exists. However, such a position completely denies both the validity of any rationale for abandoning science as the appropriate tool of analysis in the first place and the premise of cultural theory that "multiple rationalities" of equal validity exist. Indeed, Adams has fairly significantly dug himself into this position:

> Both the paradigms of science and the myths of cultural theory are powerful filters through which the world is perceived, and they are reinforced by the company one keeps. (Adams, 1998: 37).

Although he never denies the existence of an "objective reality" (Adams, 1998: 42) and refers to the "certainty" of "scientific fact" (Adams, 1998: ix), Adams, as an entrée to cultural theory, floats the idea of uncertainty being "inherent in physical nature" (Adams, 1998: 17), describing it as the position taken by the quantum physicist Max Born in a long-running debate with Einstein. While not unequivocally siding with either of these theorists, his sympathy with Born's view is clear from his introduction of the idea, his frequently insinuated rejection of certainty and physical science (such as Adams, 1998: 10 and 17) and the embodiment of uncertainty and relativist thought in his arguments. These are completely inconsistent with Einstein's cited belief "in complete law and order in a world which objectively exists" (Adams, 1998: 17). The consequence of these inconsistencies is that this book provokes considerable confusion as to where Adams has founded his thinking.

Adams' thorough and effective debunking of attempts to quantitatively measure risk is significant but not at all in discord with the idea of empiricism. If risk is a product of the uncertainty born of an absence of knowledge it has no physical existence. It is of course not possible to measure anything which does not physically exist, as Lord Kelvin's observation, cited by Adams, strongly implies: "Anything that exists, exists in some quantity and can therefore be measured" (Adams 1998: 10). Risk, it would seem logical to conclude, therefore, cannot be measured. It seems curious (in the absence of knowledge of the context of Kelvin's remark) that Adams should have so thoroughly misinterpreted him and chosen to label those intent upon measuring risk as "Kelvinists" (Adams 1998: 10). If Kelvin's seemingly faultless logic is accepted, the problem of risk measurement, which Adams has misidentified as evidence of the analytical limitations of hard science, lies with those who have erroneously attempted to extend the validity of statistical probability into the area of valid empiricism.

Finally, Adams notes the irony of the conclusions drawn by both Beck and Wildavsky, who having "argued the case for the cultural construction of risk, both conclude that what is needed is better, more critical science, and improvements in the conduct of scientific debates" (Adams 1998: 184). Although not concurring with this view and offering no prescriptive advice on the management of risk himself, Adams does not distance himself from the other two theorists' perception of the problem "as one of liberating science from the oppressive grip of the dominating hierarchy" (Adams 1998: 185). Perhaps the remedial approach is simpler – the understanding and practice of science according to its original principles.

Aaron Wildavsky

Aaron Wildavsky (1930-1993), a leading scholar of risk, was Professor of Political Science and Public Policy at Berkeley. His published work on risk is considerable and apart from several important publications consisting entirely of his own writings, includes "Risk and Culture", written in collaboration with Mary Douglas, a British anthropologist noted for her work on the cultural dimension of risk.

Wildavsky's approach to risk is decidedly mistrustful of the direction taken in western political development during the third quarter of the Twentieth Century and can be strongly identified with the peculiarly American, historical, mainstream values centred around individual, economic autonomy. It follows that his understandings of risk and the political process are consistent with and inseparable from a *laissez faire*, economic viewpoint.

A fundamental Wildavskian observation is that safety and danger are "intertwined" and thus "inextricably mixed, [so] it is not possible to have one without the other" (Wildavsky, 1985: 16). A classic example of his is the "Jogger's Dilemma" (Wildavsky, 1988: 1-14; Smith, 1995: 2): a risk of not being a jogger lies in vulnerability to heart attack, but a risk of jogging is that it may trigger a heart attack. The dilemma results from the integration of the ultimate cost (heart attack) with both of the alternative courses of action (jogging and not jogging). According to Wildavsky, it is not possible, either predictively or practically, to isolate the cost factor of heart attack from either of them. The conceptual consequence of this is that, in the predictive and practical business of risk analysis, no course of action can be trusted to provide absolute safety. However, continues the argument, while the general inseparability of safety and danger is absolute, certain courses of action are likely to provide more safety and less danger than others, so *relatively* safe courses of action may be sought. Smith paraphrases - "To make our lives safer, we must prudently accept the introduction of new risks" (Smith, 1995: 2).

This understanding leads to a second important concept of Wildavsky's, which is that "relative safety is not a static but rather a dynamic product of learning from error over time" (Wildavsky, 1985: 5-6). "Without trial there can be no error, but without error there is no learning … Knowledge grows by criticising the failure of existing theory to explain or predict events in its domain of applicability" (Wildavsky, 1985: 1). Smith succinctly summarises: "we search for safety, … [so it] is discovered – not designed" (Smith, 1995: 2). "Trial and error" is a colloquial term, its existence indicating the ubiquity of the concept, which "has seeped so far into the collective consciousness that it has become a stock phrase" (Wildavsky, 1985: 2). It might also be noted here that, more than being socially entrenched, it is a cornerstone of science. Scientific experiment applies the notion of trial and error in the form of tests of small-scale models (with small-scale errors) which may provide reliable indications of full-scale outcomes.

The same idea can also be implied by the word "experience", a valued human quality which is often used to infer a practical understanding of strengths and failings acquired through the learning process of doing something. "The debate on risk", writes Wildavsky, with reference to risk aversion, "proposes a radical revision of this practice. If we have to guarantee no errors before we start, then we cannot start at all" (Wildavsky, 1985: 2). From this perspective, then, risk is unavoidable and necessary if the human condition is to continue to change, whether of its own accord or in response to changes which occur in our environment.

Wildavsky argues that as acquired "resilience" is a product of exposure to varying environmental conditions (discussed below), national health and wealth are promoted by "private markets rather than public agencies", through their inherent tendency towards "larger rather than smaller numbers and extents of risk" (Wildavsky, 1985: 14). He also argues that "wealthier is healthier ... [being] a measure of our ability to fend off disasters" (Smith, 1995: 2).

> Contrary to common opinion, living in a rich, industrialised, technologically advanced country that makes considerable use of industrial chemicals and nuclear power is a lot healthier than living in a poor, non-industrialised nation that uses little modern technology or industrial chemicals. That individuals in rich nations are far healthier, live far longer, and can do more of the things they want to do at corresponding ages than people in poor countries is a rule without exception. (Wildavsky, 1993: 1).

In a paper analysing the connotations of mortality statistics from 1850 until the late Twentieth Century (Wildavsky, 1993: 1-4), Wildavsky contends that the capitalist system, economic efficiency and the march of modernism (all perceivable as products of "resilience"), are responsible for the superior condition of western nations and populations, in comparison to the ex Soviet bloc countries and peoples. It is an argument backed by strong evidence, but his further assertions (Wildavsky, 1993: 6-8) that people are constitutionally incapable of arriving at any useful predictive understanding of, or general agreement about risks, is overwhelmingly hypothetical and thus, much less convincing.

The keystone of Wildavsky's risk construct is his identification of two differing approaches to risk, which he calls "anticipation" and "resilience". His assertion that resilience delivers to communities far greater long term benefits amounts to a "challenge … [to] the common belief that risks should be avoided [and] that we should always look before we leap" (Smith, 1995: 2).

The conceptual origin of this idea as it is put in the pithy "Trial Without Error" (Wildavsky, 1985), lies in the Darwinian principle of evolutionary adaptation to the environment. The argument effectively forwarded by Wildavsky is based upon the notion that adaptation to a stable environment renders a species vulnerable to harm from subsequent environmental change, whereas adaptation to an unstable environment renders it more resistant to such environmental change (Wildavsky, 1985: 9). He draws on the 1979 work of ecologist C. S. Holling which refers to "thirty years of data collected for every major forest insect throughout Canada by the Insect Survey Program of the Canada Department of the Environment" (Holling in

Wildavsky, 1985: 9) to substantiate this as an observable phenomenon in natural systems. Then, in a great bound of logic, Wildavsky declares:

> Though the language of Holling's theory is abstract, its policy implications can be made quite concrete: the experience of overcoming danger increases safety, whereas continuous safety is extremely dangerous to the survival of living species. Keeping out of harm's way … is harmful. (Wildavsky, 1985: 9).

It is thus in empirical entomological evidence that Wildavsky roots his argument that economic resilience may be engendered in human communities via public policies promoting risk. The possibility of humans learning about themselves from the evolutionary features and patterns of other creatures, including insects, is well established in the history of science. However, satisfactorily justifying the validity of a claimed human policy need on the basis of observed characteristics of insect communities demands very clear lines of logic, which in this case are absent. The insect example can provide no more than a confirmatory comparison at most, but even then is of no value unless parallel structures and processes are shown to be present. To do so would appear to be a disproportionately challenging task.

In contrast to this quality of "resilience", says Wildavsky in continuance of his argument, that of "anticipation" underlies prevailing approaches to regulation (Wildavsky, 1985: 10) and leads to "the facile conclusion that the best way to protect people is by reducing the risks they face, rather than by enabling them to overcome dangers" (Wildavsky, 1985: 9). Regulation, he says, "is a form of anticipation … [which] cannot wait for evidence from actual events" and "requires bureaucracy to enforce standards". In contrast, "resilience is based on self-regulation by the people who are closest to the scene and who, therefore, have the best information about what is happening" (Wildavsky, 1985: 10).

Beyond these central but unfalsifiable ideas, founded upon simple observation and rational construction, rather than clear and hard evidence, Wildavsky sought sociological explanations for his propositions in cultural analysis (Smith, 1995: 2-3; Wildavsky, 1993: 6). In this regard he shares a good deal of common ground with John Adams and Mary Douglas. These issues are not specifically addressed here as they are substantially dealt with in discussion of the ideas of the other two thinkers. However, it is re-emphasised here that the main problems perceived to lie in these understandings is their arbitrary (that is to say, non-demonstrable) nature and their inability to satisfactorily resolve the dilemma they create for their own credibility through their failure to adequately define and accommodate empirical evidence. Relativist theory must reject the ultimate validity of empiricism in order to sustain its own validity, but the denial of the existence of a fundamental level of human perception and communication is a denial of the possibility of any useful form of logic or communicable thought.

Critical Analysis of Wildavsky

Since Wildavsky's definitions will be scrutinised below, it is necessary to point out at the outset that the keywords "anticipation" and "resilience" are not neutral terms. Anticipation is a word, often used negatively, that can imply presumption with regard to speculation concerning the essentially unknowable future. It is a word that seems, therefore, to have been chosen for its emphasis on the weakness and naivety of the position of those practicing, or believing in, the practices associated with the predictive determination of dangers. It is, therefore, to some extent pejorative. Resilience, on the other hand, is a completely positive word that conveys ideas such as stamina, strength, flexibility and survival. While these ideas are consistent with Wildavsky's broader case and were presumably selected for that reason, their use detracts from unencumbered expression of the ideas entailed. Perhaps less suggestive words, such as "projection" and "experience" would have served cold logic better.

A broad problem of inconsistent argument is identifiable within the body of Wildavsky's writing on risk, which pertains to matters close to the heart of his thesis. Although not negating his postulations, this inconsistency can be understood to significantly weaken his position by blurring contrasts that he has sought to maximise.

Wildavsky's asserts the superiority of (free-market/small government/risk taking) "resilience" over (centrally planned/over regulated/risk averse) "anticipation" (Wildavsky, 1985: 9-16; Wildavsky, 1993: 1,7), unfavourably comparing the ex Soviet bloc nations with the west. This understanding is clear and quite acceptable as a rational, explanatory analysis of fundamental differences, between the Soviets and the liberal west, in approaches to government and the resulting outcomes. However, that view is difficult to reconcile with his diagnosis of "anticipation" or "risk aversion" as a fundamental political and economic problem for the west. It is hard to accept that the stark, causative notion of risk aversion can be applied simultaneously to the failings of, on one hand, a decayed Soviet bloc (compared to "democratic and industrial societies" [Wildavsky, 1993: 1]) and on the other hand, to the USA itself, with the disaster of Three Mile Island held to be the consequence of anticipatory, bureaucratic activity.

Bluntly, the advanced west of the late Twentieth Century can either provide convincing evidence of a resilience inherent to capitalism, or strong evidence of the trap inherent to "anticipation", but not both. It is either in an advanced condition because it relies on resilience, or it is threatened and limited in its potential because it relies on anticipation.

Although it remains possible to argue that a definitional change of stance has occurred in the west, it becomes necessary to show that this is inconsistent with fundamental western aspirations and thus constitutes a structural change rather than a logical political development. It might also be suggested that it is the *degree* of anticipatory activity that is critical to outcomes rather than its mere existence, hence allowing both assertions to hold. But in either case, the clarity of Wildavsky's position seems severely compromised by the attempt to identify anticipation and risk aversion as the root of so many ills.

This inconsistency invites further criticism. If the record of western, liberal, capitalised democracy in the late Twentieth Century provides a good example of the prosperity and efficiency achievable by human communities (Wildavsky, 1993: 1), why, in the first place, seek a significant flaw in its culture? More importantly, why and how does its fundamental, analytical (or anticipatory) approach to problem-solving demonstrate a profound weakness? For the attempt to understand the nature of the material world and to thus construct certainty for humanity is the quintessential practical intent of scientific enquiry. When Wildavsky denounces "anticipation", he inevitably denounces scientific enquiry.

Science, like any other intellectual tool, can be applied and it can be misapplied. But if, as Wildavsky implies, the Enlightenment has delivered and continues to deliver so much, why should the failure of modern political culture to provide immediate and faultless solutions to the plethora of problems provoked by the rapidity of technological development (and which are only apparent anyway because of scientific understanding), be sheeted home to the Enlightenment concept of scientific analysis? For effectively, this is Wildavsky's position.

Is Wildavsky seriously suggesting, given the successes of the liberal west, that we abandon the intellectually disciplined and deliberate approach of science for some kind of restrained anarchy? Apparently he is not. In the last paragraph of "Trial Without" Error he provides what is interpretable as an ironical repudiation of his own approach:

> Looking back at the past quarter century, living standards have risen dramatically and along with them, morbidity and mortality have undergone substantial improvements. Why, then, is there so much distrust of the Western institutions that have been, on any criterion of safety achieved anywhere in the world at any time, so successful? For the escalating concern over risk to the human body and natural environment stemming from technology is exactly a referendum on these institutions. (Wildavsky, 1985: 19).

Wildavsky, it seems, is premising his thinking on an assumption that "anticipation" is a new phenomenon which has intruded onto the territory more properly occupied by "resilience". It can only be concluded, therefore, that he does not perceive a strong conceptual link to exist between the ideas of "anticipation" and "science", which means they require definition if this difficulty is to be clarified.

"Anticipation" (or risk aversion), as Wildavsky sees it, is the attempt to discover the outcome of an activity before doing it, effectively elevating theoretical construction, or projection, to a decisive level of function (Wildavsky, 1985: 5-6) so that "potential dangers are averted before damage is done" (Wildavsky, 1985: 9). He identifies "resilience", the product of trial and error as the obverse (and far more effective) means of arriving at the same awareness (Wildavsky, 1985: 5-9). Wildavsky's "resilience", as his entomological example shows, refers to a purely practical process - learning from experience. Thus his differentiation between "anticipation" and "resilience" is in essence a distinction between theoretical and practical approaches to determining risk.

The term "science" does not require particularly precise definition for the immediate purpose of this discussion. It may reasonably be described as the intellectual tool that modern human communities have developed for the specific purpose of understanding the nature and behaviour of matter. Common usage of the term is adequately covered by the "experimental investigation and theoretical explanation of the nature and behaviour of phenomena in the physical and natural world" offered by the Penguin Precise English Dictionary (2001: 792). The critical duality of the nature of science implicit in this definition is the primary point to be noted here. Essentially, if we accept this, the effective practice of science must involve a combination of both practical and theoretical skills. The elemental scientific notion of cause and effect involves the inextricable marriage of the two essential conceptual threads. Always, in science, an abstract *theory* explains a practical *observation*. In isolation, both theory and observation amount to nothing more than just that - theory or observation. Neither on its own constitutes science. Consequently, Wildavsky's dichotomous (theoretical *versus* practical) description of the possible approaches to the determination of risk is incompatible with the concept of science. His understanding demands that, for the purpose of determining risk, the idea and the practice of science be torn into two halves, both of which alone are useless for arriving at coherent conclusions about the physical world, and that a choice be made between them. For the purpose of risk management, then, Wildavsky offers us a contrived and unrealistic choice - *either* theory *or* practice, anticipation *or* resilience, speculation *or* experience (Wildavsky, 1985: 9; Wildavsky, 1993: 7; Smith, 1995: 2). There is nothing obvious in the nature of the world or human understanding of it that justifies the idea that the key to the cognisance of risk lies in this pointless dichotomy.

The concept of attempting to manage anything at all in the real world by a process involving abstract analysis alone is in itself nonsensical. Our material environment is perceived in practical, comparative ways through our senses. Theoretical understandings about it cannot even exist, much less be communicated, without information that is perceived in such fundamentally practical terms. Theory (and theoretical projection) involves and (if it is to have any point) is entirely *about* practical things.

At the other conceptual extreme, insect communities have (we understand) no intellect or capacity for abstract thought and cannot, therefore, do other than "learn" by trial and error – or experience. The powerful human ability to construct sophisticated abstractions and to imagine the future, *combined* with our other great asset, the developed ability to be aware of and to objectively observe the material world, is exactly what sets us apart from other creatures and has allowed us to analyse and manage our physical environment. Wildavsky's postulation that the promotion of resilience provides the best solution to risk management ignores this marriage and relegates us to the deprived intellectual state of Holling's insect communities that have no choice other than to merely react to the buffetings of fate.

In a discussion of the "processes" of bureaucracies and markets, which in the Wildavskian construct are, respectively, logical extensions of the abstract and practical, he dismisses the notion of drawing from both as impractical:

> Ruling out Goldilocks' strategy of getting things just right as beyond cognitive and collective capacities, my last reformulation goes, would people be better off having their porridge too hot (ie too much risk) or too cold (too little risk)? Which horn of the dilemma of risk taking – anticipation or resilience – do we wish to grasp? (Wildavsky, 1985: 14).

The question is not rhetorical. Wildavsky's answer, which is that it is resilience that should be grasped, is clearly put in the subsequent paragraph "more people will be healthier by taking larger rather than smaller numbers and extents of risk" (Wildavsky, 1985: 14). His following example of resilient and anticipatory approaches to criminal justice, in fact identifies the palpable inadequacies of both resilience and anticipation alone, but curiously he leaves this quite critical difficulty for his thesis almost completely unresolved (Wildavsky, 1985: 15). No further alternative to the shortcomings of anticipation apparently exists, other than to simply accept the inevitability of collateral damage inherent to a resilient approach. However his reasons for not looking to the middle ground, for having dismissed other options as "Goldilocks's strategy of getting things just right" (Wildavsky, 1985: 14), are neither properly explained nor apparent.

The ultimate consequence of all this is that Wildavsky's notion of anticipation and resilience is highly significant to the extent that it recognises the existence of both theoretical and practical dimensions of risk and its analysis. However, as a useful framework for analysis and management alone, it makes very little sense. Firstly, it ignores the fundamental dichotomy of risk that demands an analytical distinction be made between perceptive and scientific factors and, secondly, while effectively identifying the practical and theoretical components of scientific analysis, it fails to perceive their vital interdependence. Wildavsky's view that experience is the key to risk management is at best only half an answer.

The perhaps cognitively even more basic idea of Wildavsky's, that safety and danger are "intertwined" (Wildavsky, 1985: 16; Smith, 1995: 2) is a premise that also deserves careful analysis. It proposes that safety and danger, labels for the two alternative human conditions constituting the dilemma central to a situation described as involving risk, are analytically and practically inseparable. "With good and bad inextricably mixed, it is not possible to have one without the other" (Wildavsky, 1985: 16). This understanding effectively paints the concept of risk into the problematic corner of non-susceptibility to analysis, from which Wildavsky is later able to rescue it with his anticipation/resilience management framework.

As a contravention of what must be the most basic principle of scholarship, which is that no problem of a material nature should be considered to be intrinsically beyond the reach of human reason, a claim such as this requires considerable justification. The realm of completely abstract thought, though never entirely dissociated from worldly realities, can be reasonably said to incorporate "mysteries", which may be debated, but not settled. These are cases that cannot be proved or disproved to the general satisfaction by means of evidence and reason, but instead are practically resolved by substituting belief for rational certainty. Belief can create subjective certainty where evidence and reason, for one reason or another are unable to provide rational certainty. It is on this basis that the roots of cultural identity can be understood to be belief, rather than reason.

However, the treachery of belief, as we all know, lies in this very dissociation from reason and its ensuing propensity to engender cultural clashes. In asking us to "believe" that safety and danger are inseparable, Wildavsky is asking us to embrace an assumption based upon a simple observation (such as the existence of a relationship between heart attacks, jogging and not jogging) and not upon sound logic or evidence. He tells us that we cannot have safety without danger, but there is no good reason to accept that this is the case.

Safety is not danger and the cost of an action is not the same thing as a benefit of the same action. In cases where a cost is linked in a fixed way to an activity involving a benefit, such as in that of omelettes and eggs, no risk exists. The loss of the eggs is a certainty, not a possibility.

In cases of risk, on the other hand, only a possibility of costs being incurred is involved. Hence the relationship between an activity and a cost is not fixed - the execution of the activity will not definitely incur the costs. The benefit is usually fixed to the activity, creating the incentive to undertake it, in the face of the possible cost, but the linkage of benefit to cost is far from certain and cannot therefore be said to be inseparable from it. The very existence of the possibility that the cost may not be incurred completely negates Wildavsky's assertion that cost and benefit (or safety and danger) are intertwined.

A case in point is Wildavsky's jogger, the middle-aged health seeker of the 1980s. With the fruits of considerable scientific enquiry to draw upon, it is possible for middle-aged health seekers of the new century to reap the health benefits of jogging without risking its costs. Low cholesterol diets, good medical advice and low-stress forms of exercise have all but eliminated the risks of keeping fit. It is possible to both model an individual's vulnerability (practise anticipation?) and design an appropriate exercise regime (promote resilience?), thereby separating safety from danger. A policy approach to the risk of jogging based upon Wildavsky's understanding could only categorise the jogger's dilemma as a mystery and allow people to make their own, uninformed decisions as to whether jogging would cure or kill them.

A last and slightly less tangible criticism of Wildavsky's analysis arises from his recourse to the broad sweep of cultural explanation as a means of resolving the inconsistencies and confusion alluded to above. Having declared humans incapable of untangling the complexities of risk, he seeks explanation in cultural theory (Wildavsky, 1993: 6), which has the characteristic of sidestepping clashes of rationality and subjectivity by turning this vice of analytical challenge into the virtue of human diversity. "Nobody is wrong" is the lofty conclusion of this so-called analysis.

By admitting this relativist construct into his thesis, Wildavsky drives the cause of the understanding of risk into an intellectual cul-de-sac. His solution, as we have seen, is to take refuge in pragmatism in the form of his "resilience" option. But the abandonment of the path to understanding brings another difficulty. He has exercised his subjective judgment, not reason, in arriving at this point and is forced to continue doing this in order to reconcile the empirical evidence of Kahneman and Tversky (Wildavsky, 1993: 6-7) with his chosen destination of "resilience". "Individuals", he writes in summary of their research,

> are very poor judges of probability. More important, perhaps, is their general conservatism; large portions of people care more about avoiding loss than they do about making gains. Therefore, they will go to considerable lengths to avoid losses, even in the face of high probabilities of making considerable gains. (Wildavsky, 1993: 7).

Irrespective of the conclusions drawn by Kahneman and Tversky, this view is Wildavsky's interpretation of their work. Not only are people unable to agree about risk, he is arguing, but they are unaware of its true nature and thus incapable of being trusted to make the correct decisions with respect to its management. However, Wildavsky himself is less confused. His prescription for the malady of wishing to avoid danger is not to explore the issue and understand it, but to somehow impose the "tried and true" practical remedy of resilience upon communities. As an example of presumptuousness about the human condition, it is comparable with Marx's patronising "false consciousness" thesis and possibly no less dangerous in the wrong hands.

Robert Formaini

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[3] The Austrian School, also known as the Vienna School or Psychological School of economics grew up around the ideas of Karl Menger in the late Nineteenth Century. It is essentially subjective in its analytical approach and study is always focused on the individual. Human behaviour is considered too complex for meaningful analysis and costs and benefits are regarded as unmeasurable due to their subjective values. Classical statistical methodology is rejected on the grounds of the prohibitive complexity of human behaviour. The Austrian School stresses the undesirability of government intervention in the market.

[4] Formaini's ideas and form of argument are very comparable to those of Wildavsky, to whom he refers more than once in the text. It would seem that both share a common political outlook. Both attempt to theoretically isolate predictive theory (Formaini's objective analysis and Wildavsky's "anticipation") from experience (Formaini's subjectivity and Wildavsky's "resilience") finding fault with the former and favouring the latter. Neither considers the possibility that these things might operate as integrated parts of a much greater functioning whole, while actually having no independent existence of their own. Although apparently attempting broad engagement with the concepts of risk and public policy formulation, both can ultimately be perceived to be selectively focussing on partial information in order to argue the superiority of a policy-formulation system that is based on and serves the interests of free market theorists and players.

example: Formaini, 1990: 97) and Formaini's work effectively engages two distinct arguments that have been put in respect of this debate.

Firstly, he is concerned to refute the notion that "scientific measures of analysis permit objective scientists to determine which programs best promote social welfare" (Gordon, 1991: 129), particularly in respect of risk evaluation and cost-benefit analysis. Formaini's purpose here seems to be to challenge the credibility of central planning in any form or at any magnitude, this being the most obvious (and widely accepted) philosophical alternative to the free-market approach that he clearly favours. Categorising central planning with "technocracy ... and bureaucratic decree", he declares that they "can never be successful substitutes for markets" (Formaini, 1990: 97).

Secondly, his case challenges the relevance of the significant body of criticism of free market economics that seeks to exploit a perceived reliance on empiricism. He thus (presumably) seeks to bolster the legitimacy of free market economics by invalidating any assertion of dependence upon a methodological approach that he regards as vulnerable[5].

[5] A further, less direct, but nonetheless tangible, advantage Formaini's case brings to his own scholarly/ideological position is that the rival "British School" of free market thought, founded upon objective methodology (Formaini, 1990: 25-32) is effectively excluded from the main arena of economic debate if his arguments are accepted.

Two qualities of debate in particular stand out in this book. The first is that Formaini's research and argument are meticulously undertaken and his discussion is filled out with careful consideration and explanation. As a consequence, the sheer weight of detail alone is a formidable deterrent to critical scrutiny - a response at least as long as his book, matching paragraph for paragraph, would be necessary to deal with his arguments in full[6]. The second point is that his argument is made in several ways[7], so no major possible means of invalidating objective analysis seems to have been neglected[8]. In broad terms, Formaini claims that, as a basis for public

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[6] In the constrained context of a brief, critical summary, engagement with the minutiae of Formaini's work and detailed exploration of the subject matter are not possible. Nor is it really feasible to encapsulate the sense of his highly detailed, disjointed, frequently aggressive and sometimes wandering style of argument. Ultimately, if his arguments are to be seen as convincing, they must be justifiable at a macro-conceptual level - that is in his fundamental understandings, which are outlined early in the book. Similarly, potential weaknesses are likely to lie in the elemental assumptions upon which his work is premised and in areas he has *not* discussed, rather than those he has.

[7] As an instrument of scholarly attack, this approach could be said to owe more to the shotgun than to the rifle, an observation not intended to be pejorative, but descriptive. Simple, linear logic may be a devastatingly effective weapon in debate, but is vulnerable to simple counter logic, which may easily negate it. Multiple points of argument, even if involving only a single basic notion, can advance that notion from many differing perspectives, each of which may need to be negated in order to effectively refute the entire argument.

[8] Rather than articulating a straightforward linear sequence of logic to establish his position, Formaini's forensic approach is to seek multiple points of vulnerability in the arguments he seeks to refute and to simultaneously advance his own position as the alternative. A favourite tactic is to present an issue as a dichotomy and to justify the validity of the view he wishes to advance by undermining the other. (For example, the division of probability into objective

decision-making, scientific analysis is not (in the statistical sense) reliable[9], that it is constitutionally incapable of ever being reliable and that even if it were, its validity would always be arbitrary and uncertain.

The Essentials of Formaini's Case

In his introductory comments, Formaini identifies "the objective nature of the reality which surrounds us" and "the ability of our techniques accurately to explore and to control that reality" as "main assumptions" constituting the "framework" within which "public policy in the United States is debated analysed and implemented" (Formaini, 1990: 1). He suggests that confidence in public policy:

> is not a function of the objective reality we seek to model, but is rather the result of our having accepted the pronouncements of philosophers, scientists, consultants, policy analysts and others who have succeeded in convincing most people of the efficacy of their methods of analysis. (Formaini, 1990: 1).

It is, therefore, unsurprising that in this introduction he anticipates the conclusion of his analysis thus:

> Scientifically based (i.e. *justified*) public policy, a dream that has grown ever larger since the Enlightenment and that, perhaps, has reached its apogee

and subjective and risk assessment into deductive and inductive approaches [Formaini, 1990: 13, 12]).

[9] His central "idea" – his sole theoretical point really - is that scientific objectivity is not realistically attainable, and he argues and illustrates, then re-argues and re-illustrates this, resting his assertions on the authority of such scholars as Bayes, Menger, Hayek and Weber and citing frequent fictitious (and it must be said, usually calculated) examples of contemporary public policy to demonstrate it.

> towards the close of our own century, is a myth, a theoretical illusion. It exists in our minds, our analyses, and our methods only because we seek to find it and typically, we find what we seek. (Formaini, 1990: 1).

Hence, the intent and terms of his argument are quite clear from the outset: the object of the exercise is to confute the notion that science provides the best or only model for the analysis of the human environment. "Keep an open mind," he advises,

> and realise that there may be more than one path to valuable, true knowledge of the world and its inhabitants. The scientific rationalism that has dominated the world since the Enlightenment is powerful and useful for some problems, but lacks persuasive power when applied to others; no matter how cleverly, honestly or rigorously it is carried out, it cannot free us from other decision criteria.(Formaini, 1990: 5).

Formaini applies his view of science to the theory and operation of risk assessments, which:

> play an increasingly important role in the life of the average person, since they tend to determine the regulatory decisions that are ostensibly made in order to protect people from risks that occur in the ... environments they live in. (Formaini, 1990: 7).

He argues that, their objectivity is corrupted by subjectivity, which "usually enters the methods and arguments of risk analysts via the areas of uncertainty [that] remain unexplored by current approaches".

A short, critical description of comparative risk assessment (CRA) procedures compresses the diverse and complex theoretical constructs of this concept and its applications into a mere thousand words or so and finds it wanting (Formaini, 1990: 8–11)[10]. Pointing out the essentially multidisciplinary and consequently "less quantifiably precise" nature of CRA in policy evaluation (Formaini, 1990: 10) Formaini infers an inevitability concerning drift into subjectivity and bias that renders the techniques "inaccurate" (Formaini, 1990: 11). This in turn is argued to throw doubt upon the value of conventional policy analysis *per se.*

Formaini nominates "data" as the "first problem" of CRA as a conditional consequence of its frequently being "either sparse or nonexistent" (Formaini, 1990: 11) although he neglects the rather obvious point that any analysis made on such a basis is neither objective nor scientific. Having subsequently insinuated the existence of a general suspicion of risk analysts' claims, he then declares that "frequently analysts only have highly speculative techniques based upon myriad assumptions about situations that, in some

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[10] Formaini's somewhat sweeping argument is that these approaches (the term encompasses a great swathe of highly specific techniques applicable to almost every avenue of life) are crude, arbitrary and theoretically suspect. For example, "experimental testing", cited as one of four possible methodological classes in respect of engineering safety assessment, is described as:

> an attempt to learn of such things as "failure rates" for various circumstances. This is done by using samples under predicted conditions of use and generating frequency data for extrapolation to the universe for which the study is being conducted (Formaini, 1990: 9).

One could be forgiven for assuming that the author was about to propose a revolutionary advance in testing procedure for engineering safety. The logic of environmental risk assessment is similarly dispatched entire: "health assessments data and computer modelling can be combined to make *guesses* about environmental effects" (Formaini, 1990: 9; emphasis added).

cases, have never existed" (Formaini, 1990: 11)[11]. But irrespective of data quality, subjectivity is inevitably present in CRA, he says, and the specificity of individual cases renders averages unreliable "even where relationships are rather well defined, as in toxicology"[12] (Formaini, 1990: 12).

Under the heading "Subjectivism and Objectivism in Probability" (Formaini, 1990: 12) Formaini ordains a ruling dichotomy with respect to "the estimation of risks" whereby, he asserts that "the estimation of risks can be accomplished in one of two ways: deductively or inductively" (Formaini, 1990: 12). In pursuit of this idea, which reflects a long-established academic debate within the world of statistical analysis, he discusses in the following eight or nine pages two conflicting approaches to probability. One of these ("Laplacean", representing the current *status quo*) is, he argues, in essence,

[11] Although not citing Adams, he also identifies the subjectivity of risk as a complicating factor in analysis, using the example of accidents commonly (and counter-intuitively) increasing at dangerous intersections after the installation of traffic lights (Formaini, 1990: 11).

[12] With regard to this example, it must be remarked that he does not enter into any of the highly pertinent detail regarding the frequency of individual variations from statistical norms in toxicology, or explore the (presumably extant) scientific explanations of their occurrence. He restricts his commentary to a water-muddying inference that such complex problems are well beyond the scope of science: "individuals respond differently because of their not easily understood internal mechanisms, which in turn rely on the interaction of both the body and the mind" (Formaini, 1990: 12).

theoretical and objective and the other ("Bayesian")[13] in essence, empirical and subjective[14]. Having thus defined the debate, it really only remains for him to underline the methodological doubts and disagreements, for virtual completion of his argument that objective science and probability fail as reliable instruments of analysis and that his ultimate prescript, normative judgment, is unassailable. A critic puts it this way:

> As Formaini shows, the two variant approaches sometimes arrive at different estimates of probability for the same case. If so, the scientific pretensions of non-market decision makers already seem shaky. If no consensus exists on the way to estimate probability, how can it be claimed that there is a scientifically objective way of calculating benefits and costs? (Gordon, 1991: 130).

Formaini's case is that "Bayesian" analysis, as an inductive and subjective process, offers a better alternative as it considers data more inclusively (being intrinsically non-deductive) and it is not premised on an objective (and,

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[13] Bayesian analysis is an approach to probability revolving around a theorem articulated by the Eighteenth Century English mathematician Thomas Bayes, which provides a means of solving complex questions involving multiple probabilities. Although lending itself to inductive analysis through its ability to incorporate new data into an existing probabilistic calculation, and thus also useful to subjectively inclined analysis, through its capacity to incorporate subjective estimations of bias, it is intrinsically neither subjective nor inductive. It is simply a mathematical expression of logic.

[14] This dichotomy can be understood to be conceptually very close to the Wildavskian "anticipation" and "resilience" construct of the possible forms of risk management, which similarly considers theory and practice as mutually exclusive alternatives that comprise the entire range of possibilities.

therefore, constrained) understanding of risk (Formaini, 1991: 12)[15]. He also contends that "one fundamental difference between Classicals and Bayesians seems to be that the Classicals see probability as inhering in the things being analysed, while the Bayesians see it as states of subjectively held beliefs about those same objects and their relationships with humans"[16] (Formaini, 1991: 15).

With reference to the formation of links between theory and evidence, Formaini writes that in addition to the usual association of "scientific undertakings with induction ... there is always a good deal of deduction present in standard scientific technique"[17] (Formaini, 1990: 12). He also observes "that probability theory is not 'science' [because it is not] inductively generated or empirically falsifiable" (Formaini, 1990: 13). The

[15] He cites Parry and Winter from a 1981 article on uncertainty in probabilistic risk assessment to support this view: "Induction, as learning from experience, is just the process of revising probability estimates in the light of additional information" (Formaini, 1991: 15).

[16] However, in addition to the usual criticisms levelled at subjective analytical approaches, the routine use of Bayes Theorem may reasonably be viewed as an open invitation to the drawing of wrong conclusions. This is because it demands the inclusion of further data, but lacks any in-built means of distinguishing genuine causal mechanisms from false causality. Formaini advocates the practical utilisation of Bayes Theorem via the incorporation of subjectively estimated bias (belief of accuracy) into calculations of probability (Formaini, 1990: 22) which is a controversial and contestable position.

[17] This would have been a good opportunity to explain more exactly, perhaps with definitions and examples, the rational operation of the relationships pertinent to this topic of debate (that is between scientific enquiry, theory, evidence, objectivity, subjectivity, deduction and induction) and thus to outline his understanding of precisely what constitutes science, but unfortunately for the clarity of his argument, he takes the subject no further.

difficulty of *any* theory "being" science aside, this is a possibly valid, but highly debatable position that demands both more discussion and a declaration of commitment to a palpable definition of science before it can have any real pertinence to his argument. Superficially (that is without the benefit of this definition) it would seem a very difficult task to convincingly separate the notions of probability and empirical science[18].

Critical Analysis of Formaini

"The Myth of Scientific Public Policy" identifies some theoretical and practical imperfections, or limitations, of the scientific analysis of political problems. However, while quite valid as criticisms, these do not amount to a convincing case that conventional science is either inappropriate or dispensable as the main workhorse of useful analytic thought. Insofar as the constitution of a definitive position is concerned, therefore, it is possible to identify a number of problems with Formaini's case.

The first and probably the most important of these is the inability of his thesis to accommodate within its conceptual domain the fact of science. Formaini has not articulated an appropriate political, cultural or intellectual role for

[18] Firstly, science-based projection (by any definition) is ultimately no more than a probabilistic estimation of a certain magnitude, based upon "sample" empirical observations - even if no actual variation is ever observed. Secondly, the concept of probability is pointless and meaningless without both an empirical origin and a material application as

science, or explained its rise, the general acceptance of its validity or its apparent centrality to western, if not all, human life. Nor has he (as an inevitable consequence of this), at any point, defined science.

The discussions of science in Formaini's text, however, do *imply* certain assumptions about it. The primary claim affecting science is that of the absolute inevitability of subjectivity in human enquiry ("all evidence is filtered through human perceptive faculties") and the inferred, consequent futility of pursuing objective analysis (Formaini, 1990: 17, 33). Although this is not an invalid point of debate, he does not offer any clear definition of these terms (subjectivity and objectivity) as they function within his postulated scheme of human enquiry. Nor does he explain (beyond rather vague assertions, such as that science "flows from the processes within human consciousness" [Formaini, 1990: 33]) why or how they can be shown to have been achieved or not achieved in any particular case. In consequence his concluded notion of the ascendancy of an essential subjectivity in human perception of the material universe, while not completely unreasonable, is of limited value to his argument.

Formaini also uses a brief reference to Karl Popper's analyses to imply that the practice of science is necessarily and inarguably deductive and that any claim to the authority of science has been given the lie by Popper's famous

reference points. In other words, probability theory can have no conceptual existence or function that is independent of scientific understandings and procedures.

view that it can do no more than deductively falsify theory (Formaini, 1990: 33). However, he is less modest than Popper in asserting the strength of this claim and makes no attempt to unravel either the spirit or the letter of the philosopher's most well known understandings.

Having declared "the great questions of philosophy" to be "how do we know anything and how do we know that we know it?" Formaini makes what might be interpreted as an attempt to address the thorny issue of what constitutes science by declaring (without supporting evidence) that:

> ...most of those engaged in science accept a position best articulated by Sir Karl Popper. Selection between competing theories is to be accomplished by appealing to a repeatable process called "falsification". This process does not determine whether something is true, but rather whether it is false; this, Popper claims, is after all positive knowledge of reality. (Formaini, 1990: 33).

While this highly qualified and very limited description of science opens up issues that are critical to its nature (and that eminently suit Formaini) it does not amount to an exhaustive or otherwise satisfactory definition of the nature and function of science or an accurate rendition of Popper's understanding[19].

[19] Falsifiability, anyway, is no more than a direct, logical consequence of the probabilistic nature of science. Since empirical evidence can never be complete and certainty can never be established, scientific understanding can never amount to more than a level of probability. Absolute verification of a theory demands certainty – or one hundred percent probability – meaning that verification is *always*, in Popperian terms (contrary to Formaini's unsupported claim) at best, "provisional, conjectural, hypothetical" (Thornton, 2005: 7). On the other hand, a single evidential exception renders impossible the attainment of the required one hundred percent probability, so falsifying the theoretical principle in question.

Formaini's occasional concessions to the conspicuous necessity to find a place for science in his conceptual firmament, are exemplified by the intrinsically patronising and practically meaningless comment that "decisions will require, and *ought to have*, [his emphasis] the input of science and its practitioners" (Formaini, 1990: 97). This declaration is problematic for Formaini, as the tactic of attaching even a half-hearted sense of dispensability to science fails to address the glaring difficulty of its profound place in human (and most particularly, western) culture. His reluctance to follow his own rationale to its logical conclusion of altogether disposing of science, betrays an unsurprising lack of conviction, on his part, that subjectivity can ultimately be trusted more than objectivity.

A further concern is a vital practical question provoked by this comment of Formaini's, but which he does not address. This pertains to precisely where the role of the scientist should end and where subjective or normative judgment should begin, if the principles of science are at some point to be abandoned.

If, as Formaini argues, scientific enquiry is to be deemed an exercise of limited value and relevance, the necessary definition of the bounds of science's validity requires extremely careful consideration. The denial of the primary importance of scientific analysis in the process of decision making amounts to a denial of the capacity of scientific thought to effectively interpret the material world. (Formaini has argued this to be the case *in practice*, but not at the far more fundamental and important *conceptual* level). The discipline of science is essentially no more than a formally defined and consistently applied form of the thought processes routinely and universally used by the human mind to understand our physical environment. Materially verified theory, as the product of experience that is perceived through the senses, provides surety about the external world, without which it would be impossible to function at all. It is also logical that these thought processes are both shaped and limited by the innate physiology of the mind and the sensory resources it is able to draw on. This means that almost all sensory perceptions and the immediate understandings that they engender are common to all normal humans. It is similarly logical that such common understandings are central and essential to the formation and function of community at any level or degree. If Formaini's contentions concerning the limits of science are to be accepted and these ideas somehow embodied into processes of government, it is necessary that the ramification of his thesis, brought into focus by these observations, be addressed. Under his conditions, if public policy is to continue to have an aspirational basis in common, or shared, human understandings, some *non-scientific* means of understanding the material world (which is of at least equal merit to science) must be shown to exist and be applicable. Normative understandings do not and cannot fulfil these demands as they are not, by definition, generally shared.

With regard to the question of limiting the jurisdiction of science, the prospect of its general down-grading and the up-upgrading of subjective interpretation provokes a number of practical questions, such as: Exactly how much science is enough? When and where and based upon what criteria and principles of analysis do we accept or reject or limit scientific evidence? Who (or what sort of experts) should determine this? Who should appoint such officers or experts? How do we measure whether the experts (or their appointments) are right? Who should "watch" the experts?

A brief consideration of these questions makes it apparent that the abandonment of science as our primary means of navigating the material world would not solve the problems identified by Formaini. The same old questions concerning validity and capacity and credibility would arise again, along with new ones relating to the absence of demonstrable, universally acceptable reason. It is not the scientific process that is the source of public policy failures, but the incompleteness of our understanding, our inevitable ignorance of the future and the assumptions we must continually make about it in order to go on living.

The rejection of the principle of scientific assessment in favour of "normative policy judgments based on moral and political foundations" (Formaini, 1990:97) can be perceived to ultimately amount to the endangerment of democratic government through the tyranny of (at best) an uninformed majority or (at worst) an uninformed elite. The failures of science, which arise from gaps in our knowledge, as well as its successes, would, under Formaini's prescript, be placed in the hands of a class of decision-makers and a system of analysis, not only scientifically uninformed, but unconstrained by scientific principle. Science *is* reason and the most fundamental point of democracy is to bring reason to the process of government. A part and an inevitable consequence of this is the understanding that minorities ought not overrule majorities, but this does not mean that a minority of highly trained, recognised and respected specialist analysts whose educated opinion differs from a less informed and possibly misinformed public should be ignored. Scientific thought is not separable from the democratic process and the currency of both is due solely to the failures and distortions of the earlier, traditional subjective/normative approaches to knowledge and to government. Over emphasis of the importance of majority opinion and its application to areas where understanding is poor, is a clear corruption of the rational basis of democracy with the potential to lead to the erosion of orderly government through unreason and demagoguery.

A further difficulty for Formaini, in theory and fact, is the nature of the law as an integral component of any democratic system. Any law, but particularly democratic law, is in principle *objective* in its equal and impartial application to all citizens. It is founded upon the veracity of the concepts of objective understanding of the universe and the possibility of objective analysis and measurement of the conditions of human social existence. Evidence, in a legal sense, is a profoundly objective idea and is the determinant of all proper legal conclusions on the grounds of this very quality of objectivity.

The *objective* nature of the legal system is recognised as being so fundamental that it is enshrined in the traditional, symbolic blindness of "Justice" who objectively weighs the evidence placed before her and delivers judgment accordingly. The existence of objectivity and the possibility of its determination are at the heart of the whole concept of law and thus the effective mechanisms through which any society functions as a self governed entity. Consequently, the introduction of procedures premised upon understandings other than these would create numerous destructive tensions between the law makers, those administering it, those affected by it and those interpreting it.

A legal system based upon material evidence, objective assessment and logic cannot accommodate an inherently subjective approach to policy making. At a practical level, a law drafted according to the dictates of subjective understanding and thus drafted in ignorance of, or with disregard for the appropriate processes of objective analysis, would most probably not prove to be legally effective or acceptable. If in conflict with the existing (objectively framed) structure of law and legal precedent, it could not (or at least, should not) survive the (objectively framed) processes of legal review. General acceptance of, and agreement concerning the nature and operation of law, reflects a general acceptance of the validity of the scientific approach to analysis, as a formalised version of a human thought process that results in generally acceptable outcomes.

Even the watered down "*ought to have* the input of science and its practitioners" (Formaini, 1990: 97) concession cannot escape this logic. A process that deliberately de-emphasises the intellectual strength of objectivity and promotes subjectivity as a superior form of understanding has renounced *all* claim to being scientific or objective or just. It is not possible to be "a bit subjective" or "partly scientific" unless the areas of operation are very clearly and formally delineated as they are in courts of law where judges and juries weigh the strengths of objective evidence. (Formaini describes these resonsibilities as "inordinate burdens" [Formaini, 1990: 97].) A conceptual parallel to the legal process may be argued to in fact already exist in a system in which administrative decisions are made by a democratically accountable government that is - at least notionally - informed by scientifically derived and objective evidence.

Formaini's Approach to Argument

A significant weakness in Formaini's case is his failure to ground his position firmly in observation and exhaustive logic. Instead he obfuscates the basis and origin of his thought process by means of abstruse utterances and esoteric references. The heart of his discussion is the ultimate invalidity of objective analysis and a consequential emphasis on the validity of subjective understanding, but the rational justification for his stance is ultimately reliant upon intangible generalisations such as: "all evidence is filtered through human perceptual faculties" (Formaini. 1990: 17).

He outlines his proposition citing Bayes Theorem (Formaini. 1990: 13) and points to the intellectual positions held by Menger, Weber, Hayek, Mises and others (Formaini. 1990: 28-31) as the scholarly foundation for his views and argument, but he does not describe the logical pathways that he has followed or present any definitive rational construct.

He observes that Bayes' Theorem is associated with the subjective approach to probability and that "Bayesians" "subdivide into objective and subjective camps" (Formaini. 1990: 13) but digs no deeper. He describes Menger as the "father" of the "Austrian method" of economics and (somewhat curiously) as the "codiscoverer ... of marginal utility theory" (Formaini. 1990: 28). But his exploration of Menger's reasoning goes no further than referring to his position as being "firmly grounded in Aristotelian metaphysics" leading to a belief that "individuals are driven by psychological needs that are independent of the reasoning process, yet must be discovered by each person through his own development" (Formaini. 1990: 28). His reasons for advancing his view of the way in which people perceive the universe are never articulated as the logical corollary of a coherent and consistent human thought process. The social legitimacy and human relevance of his scholarly opinions are simply assumed.

The central weakness of a heavily deductive analytical approach, which Formaini outlines and describes in his first chapter, presents a further difficulty for his own case. He assumes an inflexible position at the outset of his argument and then searches for evidence to justify it, rather than following his own advice and inductively evaluating the available evidence in order to inform his position. As a consequence (and in accordance with his own observations about deduction) he tends to overlook factors that fall outside his conception of the issue.

Formaini's argument also has an important structural difficulty that might be considered to entirely negate his conclusions. This difficulty is that his position is variously predicated on two quite different and incompatible assumptions that are selectively applied and implied to suit specific purposes of argument.

The first of these assumptions is that the subject of his criticism, which may be described as the human approach to the problem of understanding the material universe, otherwise known as scientific analysis, is a simple, if not facile technique that is easily described and assessed. Formaini takes it for granted that "science" is intrinsically vulnerable to his methods of analysis and that he is therefore capable of objectively determining its nature, capabilities and limitations. He further assumes that these things can be meaningfully described and communicated to other people in objective terms. However, the process of the rational unfolding of a theory and its verification with the evidence of experience *is* the process of scientific analysis. While its use would be logical and acceptable if he was advocating or merely accepting of objective analysis, neither is the case.

Formaini's conflicting assumption, which he repeatedly attempts to apply as a nullification of the analytical power of science, is that the complexity of the universe and its contents renders it impregnable to the simplistic analytical techniques of science. The inevitable and ironic endpoint resulting from the identification of this conflict is that Formaini is attempting to use science to demonstrate that science does not work. A further consequential irony is that the only position that a "Formainian" could arrive at, with respect to Formaini's thesis is that it is not possible to ascertain whether it is valid or invalid.

The Usurpation of Normative Policy

Under the heading "Scientific Public Policy: A New Secular Theology" (Formaini, 1990: 69-70) Formaini asserts that science has usurped the rightful role of normative policy formulation during the twentieth century and that its merits have generally been overstated. In strongly pejorative terms, he patronises and belittles the prosecution of objective understanding while bemoaning its general acceptance. He also alleges a presumption, on the part of scientists and advocates of scientific analysis, to infallibility of method. However, he can offer very little, if any, useful evidence for any of these claims, which is consistent with the conclusion that these statements are (at best) no more than heavily biased generalisation or (at worst) an attempt to fabricate a straw man which can be conveniently dispatched.

While it may well be the case that some individuals have over-emphasised the value and role of scientific analysis in policy-making, Formaini presents no evidence that such a distortion has ever been widely or deliberately promulgated or that it has been generally accepted. Presumably this is because he is unable to do so.

While science has, quite logically, played an increasing role in policy determination as our overall scientific understandings have increased in volume, breadth, depth, detail and sophistication, western culture is now profoundly and definitively scientific and scientific understandings define almost every facet of western life. There is no evidence in Formaini's book to suggest that science influences public policy in any way, or to an extent that is not consistent with the place of science in the rest of the culture.

Contrary to Formaini's view and in accordance with the growing extent and sophistication of our scientific understandings, science can very logically be understood to have tempered the irrational and sometimes dangerous extremes of normative political decision-making. If its function has been misunderstood or its powers exaggerated, that is not the fault of science and is no reason to do other than encourage rigorous adherence to scientific principles.

Formaini offers no example or other evidence to substantiate his allegation that public policy outcomes are determined on simple scientific grounds, merely claiming that this is "beyond argument" (Formaini, 1990: 69). Science certainly *informs* decision-makers, but their decisions are ultimately the result of much more complex processes than merely following the "numbers", even when the "numbers" are determined to be the most important criteria. Judgment, as Formaini says, is always finally subjective, which is why the character and performance of magistrates and judges is so highly scrutinised. The case history of DDT, banned without scientific justification, demonstrates, quite unequivocally, that when the courtesies between a government and its electorate are relinquished, the science determining public policy is revealed to be the science of public opinion or - in Formaini's terms – normative values.

It has been pointed out that Formaini has rested his case partially on the assumption that the physical universe is beyond human and scientific understanding. This is justified on the grounds that objective certainty is undeniably unattainable[20]. However, certainty is not synonymous with understanding, which is attainable, and the two should not be confused[21].

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[20] It is a truism that scientific certainty is, in the narrow sense unattainable, but it is misleading to apply this observation as the most critical or only criterion in determining the value of scientific analysis. The findings of science are always probabilistic and often not precisely quantifiable, but these imperfections neither preclude it from being the best tool available nor justify the abandonment of its principles.

[21] With respect to toxicology, for example, he observes that "Dose/response data are averages, and individuals respond differently because of their not easily understood internal mechanisms, which in turn rely on the interaction of both the body and mind" (Formaini, 1990: 12). Formaini's clear implication here is that the complexities of the human body, including the workings of the human mind are, somehow, intrinsically beyond human comprehension or analysis, thus denying the ability of objective analysis to ever fathom them. However, there is no good reason (within or without Formaini's text) to brand any area of current ignorance with regard to the material universe as "unknowable" and there is every reason not to do so. If the purpose of scholarship is to understand, *nothing* can reasonably or safely be dismissed as "too hard" or "too complex". Besides negating the whole point of the exercise, to do so invites exclusivity, bias, error and irrationality. (For those who might argue that Formaini has deliberately avoided actually articulating his implication, it is pointed out that he cannot have it *both* ways. If his scholarly position is to be at all credible, he must either accept or reject the possibility of reaching objective understanding).

The essentiality of mystery has long been associated with religious law, which usually emphasises a severely constrained model of the human intellect and offers, as the alternative to scholarship, the acquisition of understanding from previously prepared doctrine. In his diary entry of the 5th of November, 1665 Samuel Pepys took issue with the Duke of Abermarle's chaplain for preaching on the "imperfections of humane learning." He quotes the chaplain as crying … "All our physicians can't tell what an ague is, and all our Arithmetique is not able to number the days of a man" - which God knows", the exasperated Pepys comments, "is not the fault of arithmetique, but that our understandings reach not that thing" (Pepys in Latham, 2003: 551)[22].

Formaini's Examples

The examples Formaini uses through his text to illustrate his arguments are problematic as a source of relevant substantiating content. They are frequently fictitious, rarely representative of his subject matter and at times no more than implausibile products of his imagination. They also tend to be

[22] With the benefit of almost three hundred and fifty years hindsight, incorporating great developments in science and medicine, and a commensurate decline in the influence of theology, it seems clear that Pepys, in his time, was the more perceptive judge of the path to human betterment. Like the alternative, conservative philosophy of the Duke of Abermarle's chaplain, the guidance of Formaini would ultimately lead us back to the values of the Seventeenth Century and earlier, when "normative" theological doctrine served as a significant determinant of policy.

unnecessarily colourful and emotionally manipulative in their implications. Examples are given in the notes.[23]

The book's fourth chapter (Formaini, 1990: 67-93) consists of a lengthy consideration of "the swine flu episode", during which a series of

[23] For instance, (with reference to the insoluble "Laplacean"/"Bayesian" argument) the alleged dangers of our misplaced trust in the uncertain practices of science are insinuated by a discussion of the inability of probability to determine (from two hypothetical, uninformative and ambiguous clues) whether "an enemy nation" actually intends to produce 1,000 or 10,000 tanks (Formaini, 1990: 14). The complete absurdity of this scenario is not betrayed by the gravity with which it is suggested and discussed, but the vulnerability of helpless millions to the alleged vagaries of scientific methodology and the incompetence of its practitioners is threateningly implicit in its use as a serious example.

He similarly cites an actual instance of alleged scientific uncertainty over whether alarming "chromosome damage" could have actually resulted from a New York case of toxic waste exposure (Formaini, 1990: 18), adding to the dramatic nature of his example by floating the further possibility of the psychosomatic induction of sickness and death (Formaini, 1990: 19). While Formaini does not attempt to establish what actually occurred in this case (which is intended to demonstrate the inconclusiveness of scientific analysis) the main effect of its use as an example is the emotive linking of fear and doubt to the notion of scientific analysis.

A third instance, drawn from the same chapter as the previous two, insinuates that safety from nuclear catastrophe is completely dependent upon very slender and questionable scientific resources. In a brief (and highly critical) summary of the operations of comparative risk assessment and its failings, Formaini casually suggests it "might be applied to a question such as: what is the likelihood that, in a standard water-cooled nuclear reactor, water will fail to be supplied to the central fuel core?" (Formaini, 1990: 9). He revisits the theme of nuclear holocaust a little later in the chapter, in the context of risk assessment, when he again cites this example as if it were a routine problem of probability: "What is the probability that nuclear power plant x will suffer a LOCA (loss of coolant accident) that results in a total meltdown of its core?" (Formaini, 1990: 20). In the face of such constant inferences that people are perpetually a hair's breadth from apocalyptic events, the question of his purpose in choosing such examples becomes unavoidable.

administrative blunders ensuing from a naïve, bureaucratic overreaction to a speculated "doomsday scenario" led to around fifty deaths through (as it transpired) unnecessary and dangerous vaccinations. His case is that it demonstrates the veracity of his anti-science thesis.

This is, however, a curious case study for Formaini to have chosen, for his narrative is one of high-level, bureaucratic panic, scientifically uninformed decision-making, lack of coordinated research and failure to observe the simple logic of cause and effect. It does not demonstrate a failure of science either in principle or in fact, but it does demonstrate the failure of a government body and its key individual decision-makers to apply the most basic of scientific principles to its decisions[24]. If anything, this example demonstrates the grave dangers of subjective interpretation and the need for even more rigorous adherence to the principles of objective analysis.

Formaini and Subjectivity

There is considerable evidence in Formaini's book that he comes to this debate with strong subjective preconceptions of his own with regard to science and scientists[25]. At the end of the final chapter, he quotes his

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[24] While "scientists" certainly were among these individuals, their presence in this saga does not alter one whit the crucial point that the decisions were unscientific. Even if every individual involved had been a practising scientist, the case study would still fail to prove Formaini's case, simply because bad scientists do not make science bad.

[25] This sentiment is also evident in his marked tendency to stereotype and ridicule scientists and advocates of scientific understanding and in his inclination to caricature the aspirations

grandmother as saying that "there is no damage like that often caused by educated fools" and continues:

> As I survey the entire terrain of our institutions with their expert-generated assumptions and often incredible outcomes, I begin to understand that my very uneducated relative was correct. There can never be any substitute for common sense and moral premises. (Formaini, 1990: 97-98).

Such defensive rejection of the notion of measured, scientific enquiry might be unremarkable in circumstances where the necessity for practical outcomes eclipses the need for understanding, but it is unusual and discordant in the context of academic pursuit. The purpose of analysis is to bring clarity and intellectual order to confusion by the application of detached logic. No logic can justify the rejection of objective understanding in favour of "common sense" or "moral premise" or any other prejudice in the process of scholarly consideration - or for that matter, in the process of public policy formulation.

Formaini also goes out of his way to point out that scientists "are motivated by the same desires and biases as any other person, and they exhibit the same human weaknesses from pettiness and envy to desire for wealth, fame, and power (to say nothing of absolutely pure political motivation)" (Formaini,

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of science (such as Formaini, 1990: 1, 2, 3, 8, 9, 69, 98). On the first page of his book he asserts that the general confidence in empiricism is the consequence of "philosophers, scientists, consultants, policy analysts and others who have succeeded in convincing most people of the efficacy of their methods of analysis" (Formaini, 1990: 1) – a virtual assertion that the broad acceptance of science is no more than the product of rhetoric. In the first chapter he refers, without qualification, to "the mistrust of scientists by the average citizen

1990: 3). Of course this may be true, but equally, it is no more true of scientists than of any other professional group, including academics, and so scarcely deserves particular emphasis. Its pointed mention, however, tends to imply that the fundamental and consciously held scientific tenet, of the imperative to continuously strive for objectivity, is somehow corrupt or hypocritical.

While these small points, concerning what appears to be a petty, ingrained prejudice, do not in themselves detract from the quality of his main arguments, their mention is more than mere nitpicking. The consistency and vehemence of his comments suggest that Formaini's work is not unsullied by partiality, which detracts from its scholarly stature and consequently its value. This amplifies the importance to analysis of eliminating subjective bias and maintaining neutrality and objectivity.

The Value of Formaini's Case

While the point that has just been made suggests that it is entirely appropriate for Formaini's arguments to be rigorously scrutinised, the pertinence of many of the points he raises, and the significance of his critical standpoint in the broader landscape of science and risk theory must be acknowledged.

[that] has been caused by the claims of scientists to know more than they do" (Formaini, 1990: 8).

Objective enquiry is vital to the process of understanding the material universe, but as its practitioners are usually acutely aware, the theoretical workings of objective science are ideals – always to be striven for, but rarely attained. In practice it is an imperfect analytical mechanism, but one which, by virtue of its phenomenal success since the Enlightenment, inevitably tempts complacency and the supposition that it cannot fail.

Formaini's analysis identifies and examines some of the limitations of scientific investigation that appear to have frequently been overlooked, especially in respect of environmental management, by people at all levels in the community. He provides, in the context of the simplistic view that all components of the regulatory process can be successfully objectified, a reminder that science and objective analysis have inherent constraints.

Somewhat ironically, given his views, is possible to draw from Formaini's work some quite positive conclusions about science and its role in regulating environmental risks. Providing that sufficient pertinent data is available, the delivery of a pragmatic or working level of certainty about a particular problem is a reasonable expectation, but as Formaini has shown, science cannot and should not be expected to unerringly provide infallible, objective solutions to regulatory problems. Conceptually, its level of reliability is at best only probabilistic, so its predictions must always and inevitably be regarded as imperfect and provisional.

Nor can objective enquiry be viewed as an approach that can stand alone as a means of forming understandings and making judgments. A scientific fact, of itself, is culturally inert. Objective facts take no account of human need or preference. The fact that pure water consistently boils at a particular temperature could not even be comprehended outside a quite complex, pre-existing cultural framework. Subjectivity is both inherent to and necessary for the formation of any individual or collective perception, but subjective perceptions are equally meaningless (and pointless) unless they are related to more generally agreed or shared objective facts. No amount of belief can stop water from boiling when it reaches boiling point, a fact that cannot be ignored and has to be culturally accommodated.

Unfortunately for Formaini's position, however, his contention that the analytical instrument called subjectivity can be stretched to provide more complete and useful information, while the analytical instrument of objectivity cannot, has not been demonstrated. His advocacy of Bayes Theorem as a solution for regulatory problems of multiple and complex probabilities is forensically no better supported than any prevailing misapplications of hard science to these problems, which is the approach that he is targeting.

Neither has he provided any justification for his primary assumption that objectivity and subjectivity are mutually exclusive alternative vehicles for arriving at useful material understanding, which impairs his argument. The practice of good and objective science, in the natural world or the human environment, in no way precludes the acknowledgement of subjective or cultural interpretations in the forming of judgments or the making of decisions. Were such a dualistic premise to be argued to underlie Formaini's case, it could only be replied that, he has not articulated it in his book.

For all his pertinent observations, Formaini's fundamental oversight is the function of objectivity in the processes of reason. Since humans cannot escape their own subjective and cultural perceptions, they are most crucially and usefully informed by neutral observation, which represents broader views. Consequently, more and better, rather than less, science is necessary if the process of human enlightenment is to continue.

Mary Douglas

Mary Douglas has written extensively on the topic of risk, understood as an anthropological phenomenon, chiefly in the form of essays that have been published both singly and as collections. As (in the main) a subjectively reasoned sociological explanation, her articulation of the nature and meaning of risk neither complies with, nor seems intended to comply with, the demands of objective science. Consequently, her ideas cannot be expected to either throw light on the nature of the objective elements of risk, to satisfactorily resolve specific, contemporary questions of risk, or to objectively inform debate concerning the definition or roles of science. The value of her insights lies in what they suggest about the way risk is culturally (and thus politically) understood and managed. She clearly delimits the debate she is engaging in the essay "Risk as a Forensic Resource":

> Note that the reality of the dangers is not at issue. The dangers are too horribly real, in both cases, modern and premodern. This issue is not about the reality of the dangers, but about how they are politicised. ... The debate always links some real danger and some disapproved behaviour, coding the danger in terms of a threat to valued institutions. (Douglas, 1990: 8).

However, if the constraints and ramifications of these limitations with regard to objectivity are scrutinised, the applicability of her insights to analyses, beyond those of relatively narrow academic interest, is thrown open to question. However much sociological light Douglas' analysis might be considered to throw upon the subjective motivations of those with strong views on environmental issues, it is not capable of advancing the understanding, or thus of facilitating the resolution of the material problems at the heart of these matters.

Douglas' Articulated Stance

The essential feature of her theoretical position is that danger and risk are matters that are not primarily perceived (and that are thus not primarily definable) as the objective products of observation, but are perceived in cultural terms and, therefore, should be defined, as cultural products. While expressing considerable disdain, if not hostility, for objectively focussed social sciences, such as psychology, on the grounds that cultural bias excludes the possibility of objectivity (Douglas, 1990: 10) she does not frame her view as a direct attack on the validity of hard science. Her ideas, though, are predicated on an assumption that objective science is a sterile substitute for authoritative judgment (Douglas, 1990: 12).

The genesis of Douglas' ideas lies in the difficulty that she had, as a scholar, in identifying any justification for the notion that there exists a "distinctive pre-modern mentality" which leads to the explanation of taboo through "a line of reasoning ... from misfortune to spiritual beings" (Douglas, 1992: 3). The illogic and "implicit bias" (Douglas, 1992: 3) of this position clearly rankles with her. Accordingly, she has described the persistence into modernised cultures, of a more generally observable human tendency to exploit "the political uses of natural dangers" (Douglas, 1992: 4).

In modern western culture, she argues, this is centred around the idea of risk as a consequence of technological advancement. With respect to the broader association of risk with technology, in the international community, she writes:

> A culture needs a common forensic vocabulary with which to hold persons accountable and .... *risk* is a word that admirably serves the forensic needs of the new global culture. (Douglas, 1990: 1).

Although related to a simple central notion, Douglas' expressed ideas are fairly diverse and include the following points: science can never provide definitive answers; science cannot remove the "old link" between morals and danger, because it is not the product of lack of knowledge; people inevitably want to dominate each other; knowledge exists in a competitive environment where old knowledge is constantly replaced by new knowledge, resulting in uncertainty; the idea of "risk" is linked to older notions such as "taboo" and "blame"; blame is a product of perceived danger; blame "mans the gate" and "arms the guard" in the interests of the "public good"; "risk management" security replaces the security of small, traditional communities.

Critical Analysis of Douglas

The secularisation of western society is generally accepted to have promoted individual autonomy at the expense of traditional authority and responsibility. The perceived security of the individual in a strong, pyramidal power structure can be reasonably said to stem from anonymity - the lack of individual recognition, the lack of individual intellectual autonomy, the lack of individual responsibility and the lack of capacity for individual significance. If a hierarchy headed by a powerful god is believed to be directing human affairs, there is little an individual should or can do to influence major social or political events. Movement in the great tide of human events is understood, from within such a society, to be determined by deities, monarchs, scriptures and priests. So the acceptance of rationality, science, liberal democracy and individual autonomy means the acceptance of materialism as the source of ultimate truth about the universe. The rejection of faith in gods places a corresponding responsibility for the direction of human events in the individual and collective hands and minds of human beings. This social state is, more or less, acknowledged by Douglas (Douglas, 1990: 11-13), but she considers the human environment to be, crucially, both competitive and politicised.

More fundamentally and importantly, she characterises the philosophy of materialism, the essential sub-stratum of science, as no more than a belief system involving a competitive "knowledge market" (Douglas, 1990: 11).

> No one offers us certainty, even in science. When we lived in a hierarchical culture, we used to think that either a thing was known to be true or it was wrong; a fact was a fact, and as such it guaranteed deductions made from it. Now that we are committed to an individualist culture, the competition is on; knowledge has to be defended at every point; the open society guarantees nothing. Each type of culture is based on a distinctive attitude towards knowledge. Hierarchy, both as a system of knowledge and a type of culture, assumes that the world is up to a point knowable, and that itself, the hierarchy is organised according to the principles which run the universe. Consequently, the consensus that upholds the political system upholds the authority of facts. (Douglas, 1990: 11).

While these things may or may not be so, to credibly relegate materialism and science to no more than another alternative understanding of the universe, demands considerably more logical justification than Douglas offers. Her thesis, by at least strong implication, supposes that the processes of human thought and understanding are inexorably cultural in their genesis, rather than biological, and that consequently the objectivity of science is, most saliently, no more than a form of socially constructed authority.

However, aside from heatedly disparaging the discipline of psychology (which focuses on individuals) as irrelevant (Douglas, 1990: 9-11; Douglas, 1992: 11-12; 31), she does not address the more obvious logic that groups of people reason in ways that are comparable and consequential to the ways that individuals do. Nor does she offer any direct evidential or logical basis for her belief that cultural influences upon material understanding are more significant than the basic biological functions of the human being as an animal.

The original premise upon which Douglas constructs her arguments seems to be that all knowledge is culturally defined and conforms to a "consensus that upholds the political system [and] ... the authority of facts" (Douglas, 1990: 1). The word "seems" is applied here because although (in a section entitled "Culture and Knowledge") by this means of argument, Douglas *effectively* removes the possibility of objectivity being achievable, she avoids outright denial of its ultimate possibility:

> the theme, well known to anthropologists, is that in all places at all times the universe is moralised and politicised. ... For example, a woman dies; the mourners ask, why did she die? After observing a number of instances, the anthropologist notices that for any misfortune there is a fixed repertoire of possible causes among which a plausible explanation is chosen, and a fixed repertoire of obligatory actions follow on the choice. (Douglas, 1990: 1).

Douglas thus sidesteps the more contentious and challenging, theoretical questions that such a stance would provoke. However, as a consequence, there exists in her thesis an inherent ambiguity with regard to the nature of scientific enquiry. It is very difficult to theoretically account for dangers that, as she has said, are (presumably in an objective sense) "real" (Douglas, 1990:8) but which cannot actually be objectively measured or understood by anybody since they can only be perceived through a distorting, cultural haze.

Robert Pollack makes reference to the not uncommon assertion that Douglas is an advocate of cultural relativism, excusing her on the grounds that she "discounts" objectivity "in order to emphasise the role of cultural factors" (Pollack, 1996: 29). However, probing this matter raises a series of fairly calamitous points of logic for her thesis. A critical view of her case understandably arises because she does not articulate a clear position on objectivity in her arguments. The absence of this clarification is also understandable, because commitment either way on the question of objectivity would tend to dilute and/or undermine the central ideas that she is advancing.

Were she to hold that objectivity is not possible, she would be forced into complex epistemological argument about the nature of matter in order to justify her stance. Not only would this drag her discussion into highly contentious debate along the lines of radical scepticism, but it would inevitably lead to scrutiny and criticism of the values and premises inherent to her own approach to analysis, in accordance with this view. The ultimate non-existence of objectivity would render her own observations meaningless and her ensuing generalisations (or theories) invalid. If, on the other hand, she were to assert that objective understanding is possible, her understanding that cultural analysis and cultural theory are of critical relevance would be invalidated, since the authority of objective analysis would always be absolute.

Such ambiguity and rational tension is continually detectable in her work on risk. Having seemingly declared her hand to be supportive of the idea of objective scientific enquiry (Douglas, 1990: 9) Douglas immediately qualifies her position by suggesting science is only useful "if the parties agree on community goals", a statement which takes her dangerously close to adopting a blatantly self contradictory stance. (Science either is, or it is not, objective and thus valid.) However, she uses her cultural perspective to justify her position. "Consensus," she goes on, "does not depend on the facts being recognised" (Douglas, 1990: 9) an assertion that can be logically sustained only if the human reasoning process is conceded to be unrelated to the evidence of facts.

The formation of consensus, however, must depend upon the recognition of facts as there is no other apparent, possible basis for any form of decision making. The interpretation of the word *consensus* that is salient to this view, is that it is a general agreement about what constitutes the relevant facts and what those facts demonstrate. Different facts support different decisions and the emphasis of particular facts leads to particular decision making outcomes. In 17th Century Salem, on the basis of facts that 21st Century westerners would find completely irrelevant to the issue, the consensus was that witches were living and making magic in the community. To the contemporary western mind, this logic is bizarre in its blindness to scientifically established certainties. Nonetheless, the reasoning process (and the parallel justice process) followed the entirely rational pattern of marrying observation – or facts – with theory and arriving at conclusions. Magistrates Hawthorne and Corwin, Governor Phips and Deputy Governor Danforth, the deliverers of justice in the town of Salem in 1692, would, no doubt, have been outraged at the suggestion that they had ignored or misunderstood the evidence of fact, or that their judgments were anything but fair and reasonable.

So Douglas' imputation that empirical evidence is of limited significance to political outcomes is potentially very misleading. The politically important insight behind what she has written is that expert opinion may be at variance with what the public wants, an observation that is critical to the understanding of political risk, as it has serious, practical consequences. But it is significant that Douglas has chosen to express this in a way that (as was noted above) conceptually separates the logic of consensus from the logic of science. These two thought processes (she is saying) are quite different and are incompatible, but she does not explain how understanding has been reached.

The dichotomous character of this premise forces her to then discriminate between science and culture. They effectively become comparatively situated on a gauge of worth, the nature of which also remains undefined. She accordingly ranks the analytical strength of cultural considerations above that of science, applying the supremely patronising and heavily value-laden label "culturally innocent" to the pursuit of objective analysis. The clear insinuation of this pejorative tactic is that any intellectual position seeking to establish objective truths that are free of cultural values, is ignorant, naïve and wrongheaded (Douglas, 1990: 9-10). Presumably in order to ensure that no stone is left unturned, she surprisingly and quite unnecessarily, goes on to suggest that those following such courses of enquiry consider themselves to be free of cultural bias and view members of other cultures as "Wogs" (Douglas, 1990: 9; Douglas 1992: 31).

Apart from the immediate implications of the tension between evidence and opinion, noted above, Douglas does not consider the very significant response to new evidence of accepted fact over time. Contrary to her assertion (Douglas, 1990: 9), in the longer run, consensus most certainly does depend on the facts being recognised. If this were not the case, the human race would have long lost the ability to survive in the physical world. Fairly plainly, the facts inform us about the material environment that we inhabit and, over time, their truth (or falsity) becomes quite clear, is then culturally established and, consequently, generally accepted. Cultural and personal perspectives alter as people recognise through experience the validity (or invalidity) of apparent facts and by this means accept change. In this way the west long ago rejected the validity of the supposed links between certain observed events and witchcraft, between bad smells and infectious disease, between the apparent revolving of the sun about the earth and the centrality of the earth to the universe.

Consensus, then, changes over time and, like all judgments and decision, is ultimately subjectively or culturally determined, on the basis of reasonably established facts. Even so, considered as processes of human thought, both cultural and individual forms of subjectivity are themselves fundamentally and critically informed by "the facts" of experience. A jury might, for example, on the strength of forensic and circumstantial evidence, find an accused murderer guilty because in their own experiences of real events, they have learnt to trust the consistency of patterns of cause and effect. A subsequent revision of forensic practices *in the light of new facts* might alter the individual or consensus view of the significance of the original ones. The case of Lindy Chamberlain, in which sound-deadening paint was eventually shown to have produced a positive reaction to a test for foetal haemoglobin, is a well-known example (Crispin, 2005: 5).

The arguments of Douglas probably served to dilate a constricted focus on the physical and objective aspects of risk in the times they were conceived. However, their intemperate tone and avoidance of involvement in more basic debates ultimately renders them rhetorical rather than intellectual devices. Her perceived view that objectivity is unachievable and thus dispensable as a goal, has helped steer debate about risk away from areas of specificity into less tangible arguments. The consequence is that hard evidence has become refutable and the resolution of problems through the casting of scientific light has been, to some extent, eclipsed by resolution through the wielding of political might.

It nonetheless is clear that the subjective views of individuals and communities profoundly affect the ways that risks are perceived and managed and that these understandings are essential to the understanding of the politics of risk. Although Douglas' arguments appear to have been pivotal in a de-emphasis of scientific understandings of risk, they do not alter the logic that scientific perception is the primary instrument in the human and social processes of dealing with risk. Consequently, they do not diminish the over-riding requirement of risk managers for more and better objective information.

Conclusion

This chapter has attempted to clarify some matters pertaining to the function of science by examining the work of four important scholars who have influenced the perception of science and risk during the period of the evolution of precautionary thought. The ensuing understandings support the notions that the practice of science is a natural and essential human activity, that science, by its nature, is uniquely capable of reliably providing objective knowledge of the material world and that sound scientific knowledge and good decision-making are closely associated. These ideas are further legitimised by the centrality of science to global culture and the intensification of human reliance upon science and technology almost everywhere, in the face of ongoing criticism.

Chapter 3 examines the emergence of the concept of precaution and its development into the political idea currently termed the Precautionary Principle.

Chapter 3.

THE PRECAUTIONARY PRINCIPLE

As public concern about technology has increased markedly with the rise of environmentalism over the last forty or fifty years, it is unsurprising that institutions and devices enabling a sense of public control over new technologies and developments have evolved over this period. Although the use of scientifically established standards as benchmarks for empirical soundings in environmental impact studies is now routine, the stringency of regulatory demands has tended to increase in parallel with public awareness of the environmental risks attached to technology.

During the latter part of this period, the concept of mandatory precaution has emerged as an administrative means of eliminating the risks inherent in new technology and innovative science. However, although it has been very effectively applied to prevent environmental degradation, it has also been criticised for stifling economic and social advancement and sidelining science.

The Origins of Precaution

The introduction of new technology has probably always provoked social division, but the single, most controversial technological development of the last century or so is without doubt nuclear technology. Launched into the public's consciousness in the form of the two devastatingly destructive bombs that ended World War II, it riveted the world's attention on the capabilities of science and coagulated vague doubts about the noble status of science into a more solid scepticism. Although it has subsequently been widely used for peaceful and humanitarian purposes as well as making weapons of war, the prevailing perception of nuclear technology is that it is at best a double edged sword. The strong vein of pacifism in western society has often been attributed to social memory of the butchery that occurred in the trench warfare of World War I and it can be similarly supposed that such an association may exist between contemporary environmentalism and the bombing of Japan in 1945.

Consequently, it is significant that it was in the context of a world on the brink of nuclear war that Rachel Carson's book *Silent Spring* (Carson, 2000) was published in 1962. This book famously linked the ubiquitous pesticide, DDT, with profound environmental degradation and serious human and animal disease. It quickly found a large audience that overlooked its scientific weaknesses and inaccuracies and was prepared to accept that there was a dark side to science. "Silent Spring", commonly cited as the spark that lit the modern environmental movement, is still a very widely read text in the US and revered in environmental circles everywhere. Consciousness of natural history and conservation, as they were then called, grew very quickly through the 1960s, while alarm arising from Carson's book quietly smouldered and spread. In 1972, at the peak of US political self-hate, the EPA fell into accord with public opinion and in perhaps the first true environmental precautionary action, banned DDT - against the weight of scientific evidence that showed it to be a relatively harmless and useful chemical.

Hanekamp, Vera-Navas and Verstegen (2005: 2) also identify 1972 as a critical year in the genesis of "precautionary thinking", arguing that by this time that it was already becoming a political force to be reckoned with:

> Two influential international reports gave the cultural ecological critique of green thinking intellectual (scientific) and political repute. First in 1972 Ward et al presented a report to the United Nations World Conference on the Human Environment [entitled *Only One Earth: the Care and Maintenance of a Small Planet*]. It argued that man had to replace family or national loyalties with a sense of allegiance to the planet in order to save it from destruction. ...
> Second and more known to the general public, the Club of Rome, in their 1972 report "The Limits to Growth" also projected imminent global devastation, unless resource use was curbed and resources shared... Twelve million copies of the report were sold worldwide and it was published in 37 different languages. These two reports coincided with the oil crisis of the early 1970s, which gave them economic credence and social support. (Hanekamp, Vera-Navas and Verstegen 2005: 2-3).

It seems clear, therefore, that by the time the landmark acid rain issue arose in Germany in the mid 1970s, the ideological and precedential groundwork for precautionary, political action was well and truly laid.

The German Roots of Precaution.

Despite the important precautionary milestone that DDT constitutes, the attachment of precaution to regulatory issues of technological biosafety is usually more strongly associated with Europe than America. Without EU support, opposition to GM may have remained confined to environmental groups. Within Europe precaution seems to be particularly strongly rooted in German culture and history, where purity, wholesomeness and the natural state have long been considered to provide security of health and social wellbeing. Germany's beer purity laws date back to 1516 when Duke Wilhelm IV of Bavaria decreed that lager should be made from nothing other than hops, barley and water. This condition still applies to German lagers and is voluntarily applied to most other German beers. The only concession that has been made to technology over the last half-millennium is the addition of yeast to that short list of ingredients, due to the discovery that the fermentation process is dependent upon its presence.

The secular Nazi German state, having little regard for the finer points of democratic sensitivity, imposed some quite extreme public health measures upon the German populace in reflection of the almost god-like respect it accorded the integrity of nature. This subject has been explored in several books by Robert Proctor, a Professor of the History of Science at Pennsylvania State University (Proctor, 1999).

The Nazis reinforced their view that individuals had a patriotic duty to maintain good health, with campaigns and administrative measures designed to eradicate behaviour and practices that were inconsistent with this aim. Their intention was to ensure that the workplaces of the Third Reich were healthy, that its citizens were sustained by wholesome, natural diets and that their use of alcohol and tobacco was constrained.

While describing Nazi fascism as "the low-water mark in twentieth century moral culture", Proctor also considers it to have been "a more subtle phenomenon than we commonly imagine, more seductive, more plausible … nuanced and complex" (Proctor, 1999: 8).

> People saw the movement as a source of rejuvenation – in public health and in other spheres as well. People looked to Nazism as a great and radical surgery or cleansing, and not always in ways that are abhorrent, even with the privilege of hindsight. (Proctor, 1999: 7-8).

While Germany was a world leader in many areas of science, including medicine, Erwin Leik, the so-called "father of Nazi medicine" was:

> best known for his critique of the "spiritual crisis" of modern medicine … [which was] enervated by specialisation, bureaucratisation, and scientisation, warped by greed and myopia but also by its failure to appreciate the natural capacity of the body to heal itself. (Proctor, 1999: 22).

However, the Nazi health campaigns were sullied by their links to notions of genetic pollution and racial elitism. Proctor emphasises that there is no logical link between the Nazi's quest for social purity and our contemporary aspiration to leave the natural order undisturbed (Proctor, 1999: 277).

Irrespective of the Nazis, twenty-first century western precautionary thinking does, however, have strong roots in Germany, for the formal flame of political precaution was ignited there in the 1970s.

Acid Rain and Precaution.

The observation in the mid 1970s, of yellowing, needle loss and death of spruce trees in German forests led to the hypothesis of a link with acid rain, a chemical product of fossil fuel residues from power generation and motor vehicles (Pearce, 1987: 3). Since the consequences of waiting for conclusive evidence were potentially catastrophic, the German Government acted to force cuts to emissions citing the *vorsorge prinzip* (Kellow, 1999b: 128; Takeuchi, 2004:3) which means the principle of "preventative action" or "forecaring". This precedent was the genesis of the environmental regulatory approach adopted by Helmut Kohl and sometimes known as "Green Keynesianism" or "ecological modernisation" (Kellow, 2002: 128). Certain justifying conditions and circumstances that characterise this seminal instance of openly precautionary, environmental regulation should be identified at this point, because they contrast starkly with those surrounding more recent cases of precautionary intervention, such as GM crops.

The first difference is of palpability - the problem was obvious for all to see. It was not hypothetical or scientifically fanciful and its cause appeared to be external. Secondly, the potential scale of damage was huge - the possible deforestation of central Europe was an intolerable prospect. Third, the danger was imminent - the fast rate of damage made immediate action necessary. Fourth, the science was authentic – serious concern was based on a sound hypothesis, so mainstream science was not in conflict with public opinion. Fifth, verification and closure was expected – scientific substantiation of the main part of the theory (one way or the other) was both possible and likely. Sixth, the probability of net gain was high - the likely cost of inaction could reasonably be expected to outweigh the likely cost of taking preventative action. Seventh, the steps taken were consistent with mainstream values - the preventative action taken accorded with the principles of science and with the aspirations of the community. The regulatory requirement for lower emissions both anticipated and forced technological *progress* as a remedy to the problem. The target was the damaging side effects of imperfect technology, not the technology itself.

The scientific questions raised by the acid rain hypothesis are complex and answering them involves significant empirical difficulties, which means that the whole issue is still far from fully understood. The remaining areas of uncertainty concern the movement and behaviour of chemicals in the atmosphere, in soils, in bodies of water and in plants (Pearce, 1987: 1). The investigation of acid rain has raised as many questions as it has answered but the enforced reduction of emissions ahead of scientific verification was a successful tactic. The recovery of the German forests was in fact so rapid that the whole acid rain thesis has since been questioned by some scientists (Pearce, 1990).

Nonetheless, the important and main accepted features of the acid rain story amount to the simple narrative sequence that a problem arose, logical remedial action was taken and the problem receded. The science of acid rain is an evolving body of knowledge that has never been anywhere near complete or certain, but it has, so far, managed to reliably point the way for regulators. The precis of the ongoing story is that the acid rain problem has been progressively dealt with at both the scientific and regulatory levels (Pearce, 1987: 1; Pearce, 1990; Pearce, 1996: 7) and that precautionary action delivered the Europeans a positive outcome.

Strict emission control regimes, international cooperation and steep reduction gradients for industry and motor vehicle emissions have led to drastically reduced outputs of the main chemical culprits in the formation of acid rain - sulphur dioxide and nitrogen oxides - by forcing technological advancement (Pearce, 1987: 4; Pearce, 1996: 7). These technology-driving regulatory controls can be extremely severe. A British regulatory decision of 1996 compelled electricity generators, responsible for two thirds of the country's sulphur dioxide emission, to reduce sulphur dioxide output by 85% before 2005 (Pearce, 1996: 7). This measure was expected to reduce the level of emissions of sulphur dioxide to less than 10% of the peak of over 5 million tonnes that British industry was releasing into the atmosphere annually in the mid 1970s (Pearce, 1987: 1).

The Environmental and Health Catastrophes of the 1980s

The 1979 Three Mile Island nuclear power accident was the first of a series of major catastrophes that undermined public confidence in the ability of science to lead the world forward. The Bhopal disaster in India (1984), the explosion of the Challenger space shuttle (1986), the meltdown of the nuclear reactor at Chernobyl (1986) and the massive Exxon Valdez oil spill (1989) were all massively significant failures of technology. These events punctuated a period of growing concern that human activity was irreparably harming the environment as the hole on the ozone layer and greenhouse theory became determining forces in environmental politics. Perhaps significantly, all this occurred as the maturing baby boomer generation was abandoning the discomforts of the counter culture's puritanical ideology and looking to existing economic and social structures for a future.

The accelerating efficiency of media coverage of these terrible events meant that people everywhere were graphically exposed to the dramas and tragedies of them in some detail. They also shared the very human response to them that anthropologist Mary Douglas has associated with threats to communities, which is that someone was responsible for the harm. Rightly or wrongly, the players and moral narratives described in the media were consistently recognisable and even formulaic. Following the same line of argument as the 1972 UN and Club of Rome documents, the news stories usually propagated the view that unless corporate greed and scientific ambition were brought under control, they would probably destroy the world.

The ancient cultural theme of the need for the forces of good to unite and overcome the forces of evil seems to have become dominant in western perceptions of these events. In an analysis of the roots of precaution, Hanekamp, Vera-Navas and Verstegen have linked "green thinking", as Bramwell's conjunction of "the cultural ecological critique ... [and] the scientific economic concept of non-renewable resources" with Veldman's "green thinking" as a romantic worldview with a "focus on the past ... as a guide to the future" (Hanekamp, Vera-Navas and Verstegen, 2005: 2). According to Veldman's understanding, this romantic worldview is

> centred on the conviction that modern science with all its statistical and explanatory potential cannot depict or grasp all of reality, which is experienced beyond the reach of the physical senses. (Hanekamp, Vera-Navas and Verstegen, 2005: 2).

Variant versions of this notion, suggests Veldman, have been articulated and disseminated in the writings of E.F.Schumacher (such as "Small is Beautiful" [Schumacher, 1973]), and generally popularised in the broadly appealing fiction of C.S.Lewis and J.R.R.Tolkien (such as "The Chronicles of Narnia" [Lewis, 2004] and "The Lord of The Rings" [Tolkien, 1995]). Perhaps more directly telling, the idealised mindset of green thinking is no less evident in the opening chapter of "Silent Spring", which "depicts a similar unhistorical landscape of a world past" (Hanekamp, Vera-Navas and Verstegen, 2005: 2).

Throughout the political incubation phase of the precautionary principle, further evidence of the inadequacy of science that supported the emerging deep green worldview was never hard to find. Throughout the 1980s and 1990s, the episodic development of first the HIV/AIDS epidemic and then the BSE crisis provided a constant drip of bad news about science. Kellow (2002, 115-135) has pointed to the fears raised by the BSE issue as an important source of pressure for the adoption of regulatory precaution and has identified a particular link between BSE and the formation of negative public perceptions about GM food.

At the time of the first occurrence of HIV/AIDS in the late 1970s, the last of the great infectious disease epidemics remained a fading nightmare. Although still within living memory, these memories were associated with a less scientifically enlightened and far less secure past. However, the outbreaks of BSE and HIV/AIDS dramatically dispelled any possible illusion that medical science had completely conquered infectious disease. Although, ironically, the scientific responses to these two new and unforeseen public health threats were actually prompt and effective, the hitherto heroic image of medical science and its researchers appears to have suffered significantly from the mere fact of their occurrence (Breithaupt, 2001: 12).

While a vaccine is yet to be produced against HIV/AIDS, technically speaking it is already (albeit at a significant cost) a controllable disease. The causative agent of AIDS - the HIV virus - was identified "in record time" and within 5 years of this breakthrough its genome had been sequenced, blood-screening processes had been developed and implemented and AZT trials had begun (Breithaupt, 2001: 12).

In respect of BSE, biologists swiftly "came to understand a disease that defied all attempts to explain it based on existing knowledge" (Breithaupt, 2001: 12). Stanley Prusiner was awarded the Nobel Prize for his discovery that the disease is caused by prions - "a true scientific revolution [which] gave some completely new insights into nature" (Breithaupt, 2001: 12).

The legal/regulatory establishment cannot be accused of operating with anything less than exemplary effectiveness and speed in this case either. Aynsley Kellow (2002: 134) has pointed out that the biomedical research effort was not triggered until the first positive diagnosis of BSE in cattle at the end of 1986, but within eighteen months, initial research had been completed and its findings translated into regulatory action and implemented. The consequence of this measured and efficient response was that high-risk material was quickly excluded from the human and animal food chains, so by the time the issue began to raise public anxiety the most important remedial regulatory controls had already been in place for some time.

> The BSE/nvCJD outbreak … demonstrates that we are capable of regulating risks ... By 1997 there were only nineteen established cases of nvCJD in Britain and one in France, while there were over 80 by 2001. The horrific manner of death, rather than the frequency, has heightened public concern. About one million cattle were slaughtered and Britain's beef trade was harmed, but despite the high economic stakes, scientists and regulators minimised the impact of the tragedy … The role of good science and risk management in limiting the scope of the tragedy has been submerged in a climate of dread, and the risk management success overlooked. (Kellow, 2002: 134).

The "Rio" Version of the Precautionary Principle.

The term "Precautionary Principle" has had increasing currency in political language since the early 1990s. According to Hathcock (2000, 256) the term has been derived from the understanding of precaution that was articulated in Principle 15 of the 1992 Rio Declaration, which was an annex to the Report of the United Nations Conference on Environment and Development, held in Rio de Janeiro that year.

The "Rio" version is generally recognised as the benchmark version of the Precautionary Principle. Kellow (2002: 124) refers to it as "the accepted version" and Hanekamp, Vera-Navas and Verstegen, (2005: 1) describe it as "the most authoritative among the many formulations of the precautionary principle that can be found". In this form it states that:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (UN 1992).

The UN also included what is probably a non-binding form of the Rio Precautionary Principle in the preamble to the simultaneously drafted Convention on Biological Diversity. This records the signatories merely "noting" the Precautionary Principle. The "Rio version" has since been quite widely copied at national and sub-national governmental levels for legislative purposes.

In Australia, it has been incorporated almost word for word into the Commonwealth *Gene Technology Act 2000*, [Section 4, Paragraph (aa)]. It has been adopted as a "core element" of the National Strategy for Ecologically Sustainable Development and been included "either specifically or by inference as part of ESD [ecologically sustainable development] in numerous Australian environmental statutes" (Cole, 2005: 1). These include the South Australian *Environment Protection Act 1993*, and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

At a judicial level the Precautionary Principle has been applied or considered in several Australian environmental disputes (Cole, 2005: 2-3). In 1993, Judge Stein, of the New South Wales Land and Environment Court, disallowed a NSW Parks Service permit for a local government to construct a road, and ruled in favour of a third party challenger (*Leatch v. National Parks and Wildlife Service*). The court refused the licence on the grounds that there was insufficient scientific certainty about the impact upon populations of the endangered giant burrowing frog and yellow-bellied glider. Judge Stein said that "the precautionary principle is a statement of commonsense and has already been applied by decision-makers in appropriate circumstances prior to the principle being spelt out" (Cole, 2005: 2). Stein cited a number of international judicial applications of the Precautionary Principle, in Britain, India, Pakistan and New Zealand as well as judgments in the International Court of Justice and the European Court of Justice (Cole, 2005: 4).

Cole, an environmental lawyer, considers that irrespective of its inclusion in legislation, "courts throughout the world are increasingly inclined to accept the principle as a means of dealing with scientific uncertainty in environmental disputes". His view is that it "may fairly be regarded as an evidentiary tool in resolving dispute over the risks presented to the environment and to human health (Cole, 2005: 5).

However, while it may be beyond doubt that the Precautionary Principle has been increasingly applied, its usefulness as a means of "resolving dispute" (if this means achieving general and lasting *acceptance* of decisions) is highly questionable. An appropriate legislative and judicial instrument of decision and influence, with respect to vital determinations about the future of the world's technology must surely possess integrity of the highest possible order. The frequency, consistency and vehemence of criticism of the Precautionary Principle suggests that its integrity is far from being generally established or accepted.

The Precautionary Principle is one of 27 principles contained in the Rio Declaration. A quick glance through them reveals that the others vary considerably in their purposes and merits but that overall the document articulates a good mix of practical guidelines, morals-based political intentions and ideological statements. Although not unworthy or purposeless, the Rio Declaration is essentially a loose directional agreement that, in contrast to its sister document the Convention on Biological Diversity, is too unfocussed to be enforceable and appears not to have been framed with any real sense of legal authority or intent.

In view of these observations, is unsurprising that the Rio Declaration contains many ambiguous, contradictory and vaguely expressed ideas. The foundation statement, Principle 1, for example, in its entirety, states: "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature" (UN, 1992). What this was intended to mean, in a legal or political sense, is open to conjecture. It is not clear whether humans are described as being at the "centre" of concerns because they are the main cause of environmental degradation or because they should be the primary beneficiaries of sustainable development, or both. Nor is there any indication of whether the delegates considered the life of a villager in the Andes or that of a stockbroker on Wall St to be more productive and healthy, or whether either of them should be considered to live in harmony with nature.

These are not petty or mean-spirited criticisms. If the Rio Declaration is to be accepted as a serious prescriptive document and if we are to allow the Precautionary Principle to shape our technological future, we must be certain that the values involved are appropriate and that they are accurately described. The form of expression used in Principle 1 suggests the intention of determining and defining a context for sustainable development, but as it stands it is merely suggestive of the general mood of the conference and is of little, if any, practical use.

Principle 9 (which might well have been dubbed the "scientific principle") directly contradicts the most common interpretations of the precautionary principle at almost every level. It asserts that:

> States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies. (UN, 1992).

It seems clear that the purpose of Principle 9 is to formally establish the conventional wisdom that science and innovation are central to improvement of the human condition, and therefore, also to the development of sustainable technologies.

How principles 9 and 15 are supposed to be integrated is not clear, as the question of the intrinsically probabilistic nature of scientific findings is not addressed by the Rio Declaration and was presumably not considered contentious. What is apparent from the inclusion of Principle 9 is that interpretations of Principle 15 that question the validity of science, or its ability to advance the human condition and solve problems, are inconsistent with the intentions of the Declaration.

If Principle 9 is accepted as an endorsement of science, one logical interpretation of Principle 15 is that it is a device to prevent the probabilistic nature of science from being corruptly manipulated. The wording "...lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures..." suggests the closing of a loophole, and there is no hint in Principle 15 that "lack of full scientific certainty" is anything other than normal. If this is the case, the (anyway incorrect) implication that science *can* be certain is a misinterpretation of Principle 15.

The brief but somewhat rambling, preamble to the Rio Declaration indicates that the document was intended not to be prescriptive, but as an inclusive statement of solidarity. Its "goal" was to foster consensus on the issue of sustainable development so that "new levels of cooperation" and "international agreements" would become possible. There is no suggestion that the Rio Declaration itself constitutes such an agreement. The subject matter of its principles supports this understanding. For example:

Principle 20 states:

> Women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainable development.

Principle 21 states:

> The creativity, ideals and courage of the youth of the world should be mobilised to forge a global partnership in order to achieve sustainable development and ensure a better future for all.

Principle 23 states:

> The environment and natural resources of people under oppression, domination and occupation shall be protected.

Principle 25 states:

> Peace, development and environmental protection are interdependent and indivisible.

While these principles express important and necessary intentions, and their content accurately reflects the broad ideology of the international community, as written, they have no place in a document proposing to establish practical, legally applicable rules for the achievement of sustainable development. It is very difficult to see how any of them could be directly applied in any useful way. They are, though, not out of place in a formative document outlining the aspirations and a directional framework for emerging political values.

It seems fair to conclude from the above that the purposes of the Rio Declaration and the intentions of its architects were consciously constructive and did not include undermining conventional science or its role. It is a document that sets down generally agreed ideas rather than a consistent and precise set of practical, legal rules governing an agreed international environmental strategy. Nonetheless, this does not preclude the possibility that a principle of the Rio Declaration, possessing its own internal integrity might be extracted and successfully applied.

Principles and the "Wingspread" Precautionary Principle

The word "principle" is an everyday word with the uncontroversial meaning of "an accepted or professed rule of action or conduct" (*Macquarie Dictionary*, 1991: 1403). The usual application of the word then is that it is a rule that can be applied passively (in an "accepted" sense) or actively (in a "professed" sense) but that in either case it is primarily concerned and associated with predictability of outcome. A principle essentially says "if *a*, then *b*". A principle is, therefore, more than anything else *decisive*.

Principles involve, less palpably, the idea of general acceptance on the basis of scientific, moral or legal reason. They are also by definition reductive. Whatever their context, their practical function is to provide shortcuts to desired endpoints. As such, to a greater or lesser extent, they eliminate the need for investigation and decision and provide structures that facilitate decision-making or learning processes.

As a single entity with a simple function, any particular principle, as a decisive rule, should also be reasonably expected to articulate a single, distinct, unequivocal, substantiated and pivotal idea. Multiple, subjective, vague, hypothetical or ambiguous ideas – no matter how desirable or laudable – cannot with accuracy be described as principles as they are not capable of being decisive and, therefore, cannot function as rules of action or conduct.

On this basis, there exists a considerable gap between the essential qualities of a principle and the qualities of the Precautionary Principle. A perhaps even more fundamental difficulty is that no single, generally agreed version of the Precautionary Principle exists and apart from the problematic Rio version, no attempt to draft a simple, coherent and practical precautionary rule appears to have even been made.

The Precautionary Principle is frequently cited or quoted, but it is not consistently understood as a clear idea with a clear reductive purpose. The term has been attached to a variety of ideas and intentions that have been expressed in a diversity of forms. Hahn and Sunstein (2005: 1) report that nineteen different versions have been identified, so its pivotal concept is yet to be precisely determined and the nomination of any single idea as definitive is likely to be contested.

It has already been indicated that the form found in the Rio Declaration has been most generally accepted and that it has been transferred directly to some Australian legislation. However, the more far-reaching version contained in the "Wingspread Declaration", made in 1998 by an international group of activist professionals after a two-day meeting in Wingspread, in Racine, Wisconsin, appears to have found significant and increasing, if limited support also (Hahn and Sunstein, 2005: 1; Montague, 1998; Takeuchi, 2004: 3). This version has had some influence on understandings of what the Precautionary Principle means at the legislative level, but the ideas underlying its proposals would, were it generally adopted, amount to a significant ideological shift in mainstream thought.

A memorandum to all legislators in the State of Hawaii, written by Dawn Takeuchi, a "Research Attorney" in the Hawaiian Legislative Reference Bureau, describes the Wingspread Statement as "the most well-known" definition of the precautionary principle (Takeuchi, 2004: 3). This report lists the "key components" of the precautionary principle as:

1. Taking anticipatory action to prevent harm in the face of scientific uncertainty.
2. Exploring alternatives, including the alternative of "no action".
3. Considering the full cost of environmental and health impacts over time.
4. Increasing public participation in decision making.
5. Shifting responsibility for providing evidence to proponents of an activity. (Takeuchi, 2004: 2).

The Board of Supervisors of the City of San Francisco has adopted a form of the precautionary principle defined by tenets closely resembling these points (Takeuchi, 2004: 3). Since this represents a considerable escalation of the aims of the Precautionary Principle over the "Rio" version and as it is becoming legislatively and politically influential, some analysis of the "Wingspread" version seems necessary.

The Wingspread Statement is far too long and complex to be described as a coherent or pragmatic precept. It is more a micro-manifesto on preservation of the environment and the containment of technology, premised upon the belief that technology is destroying the world. It asserts that:

> … there is compelling evidence that damage to humans and the worldwide environment is of such magnitude and seriousness that new principles for conducting human activities are necessary. … Therefore, it is necessary to implement the Precautionary Principle: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the

> public, should bear the burden of proof. ... Thus, as formulated here, the principle of precautionary action has 4 parts:
>
> 1. People have a duty to take anticipatory action to prevent harm ...
> 2. The burden of proof of harmlessness of a new technology, process, activity, or chemical lies with the proponents, not with the general public.
> 3. Before using a new technology, process, or chemical, or starting a new activity, people have an obligation to examine "a full range of alternatives" including the alternative of doing nothing.
> 4. Decisions applying the precautionary principle must be "open, informed and democratic" and "must include affected parties". (Montague, 1998).

The first difficulty raised is the assumption that the decisive regulatory action of suspending or banning technology should be taken in advance of clear scientific understanding, on the strength of a speculative "threat". Unless quite explicit qualifications, such as a time limit and a program of research were attached to such rulings, their consequences would almost certainly be irresolution and conflict.

Beyond this, the implication that cause and effect relationships can be "fully established" at all exposes a critical conceptual ambiguity within the Precautionary Principle, because the idea of precaution itself is premised on science's intrinsic inability to "fully establish" anything. Consequently, a lack of "full establishment" alone does not comprise reasonable grounds for precautionary restraint. This means that an additional, more specific condition, such as broad (scientific) peer agreement is necessary, but such a solution would be unacceptable to advocates of precautionary action as it would render the first (universal) condition of uncertainty redundant and simply replace the question in the hands of science. As the wording stands in the Wingspread Statement, it would be possible to suspend from use any technology at all, on the basis of an assertion that it comprised a biosafety "threat".

Ordinary commonsense judgments aside, precautionary bans based on suspicion rather than evidence of problems, involve the attachment of a higher value to subjective opinion than to science, and the consequences reflect this. If the logic of Wingspread had been applied to GM cotton in 1996, Bt varieties would have been indefinitely banned, while the chemical pesticide system, which was damaging the environment and destroying the industry, would have remained in place. In the case of GM canolas, some states continue to apply precautionary bans on the basis of speculated risks, leaving in place the environmentally dirty triazine-tolerant (TT) canola system and the certainty of contamination of waterways. No matter how the relationship is defined, the incompatible insinuations of precautionary action under the terms of Wingspread are that subjectivity is at least equivalent in predictive power to objectivity and that the attainment of scientific certainty is possible.

Secondly, the assertion that "people" have a "duty" to anticipate and prevent harm does not make it true or even a useful idea. "Duty" can only exist in the context of specifically defined skills, knowledge and powers. Without these preconditions, risk perception is likely to be uninformed and subjective and any action taken of arbitrary value. Ideologically justified "duty" is the stuff of totalitarianism.

Thirdly, the in-principle placing of the burden of proof of harmlessness of innovations upon the shoulders of "proponents" is, if conventional scientific values are rejected, an insistence that a negative be proved, which is not logically possible. This demand, according to Kellow (2002: 125) "is the logical equivalent of asking people to prove that they are not witches".

In a more practical sense, the insistence that developers shoulder the burden of proof of the safety of *their* technology reinforces the notion of the private ownership of ideas and must tend to confine the innovative process and the ownership of intellectual property to the richer, corporate sector of society. In the longer term it seems likely to favour the concentration of the ownership of technology and wealth among established elites.

Even so, in practice it may well mostly be appropriate for developers to bear the main responsibility for ensuring that their innovations are safe. It is not, however, appropriate that it be applied any more zealously than scientific convention suggests. Reversal of the burden of proof is an economic disincentive for innovation and must inevitably depress inventive activity, but it does not inevitably provide optimum outcomes. Rigid adherence to its dictates would most probably have prevented all the major advances since the time of the industrial revolution, including the steam engine itself. This demand is currently preventing the adoption by developing nations of GM Golden Rice, which is capable of preventing the blindness and deaths of millions of children each year through vitamin A deficiency.

Fourthly, the obligation to "consider" all alternatives including "doing nothing" when a new technology, process, chemical or activity is proposed is an unrealistic and unenforceable suggestion. Even if it were feasible to implement and police it, its main effects would be to bind technology and its developers in a bureaucratic straightjacket that could seriously disrupt market forces. It is quite acceptable for an innovation to be found to be wanting in an open and objective process, but it would be very different for it to be declared unnecessary or unwanted by regulation. In a self-regulatory environment it would be unlikely to very much change the way decisions are already made. Competent administrations routinely weigh all viable alternatives, and anyway, consideration of the option of *not* adopting technology is always implicit in its adoption. Successful commerce and business does not have a long record of financing innovation with no inherent advantage over the *status quo*.

Although it is not possible to isolate from this bundle of concepts any single idea that captures the essence of the Wingspread statement, it is a source of various possible interpretations of precaution and its elements are in close keeping with the policies of green political parties and NGOs. Even if it lacks the ultimate legal blessing of legislative enactment, the Wingspread precautionary statement appears to have at least some legislative influence and is possibly more politically effective than a more precisely defined principle would be. The continuing bans on GM canola by some Australian States is a case in point: the State moratoriums are not the consequence of a single, specific threat that might be addressed, but are the product of broadly held uneasiness about a number of vaguely perceived issues.

Difficulties with the "Rio" Precautionary Principle

Economists Hahn and Sunstein (2005: 1) warn of the need for authorities to carefully consider the consequences of formal adoption of the precautionary principle in any form because it "could lead to dramatic changes in decision making". They also remark upon the apparent reticence of the EU to commit to any specific version:

> The European Union has taken a leadership role in promoting the precautionary principle as a basis for making decisions on environmental policy and other areas, such as trade. The EU has not specified the version of the principle that it would like to use in particular settings. But it has clearly endorsed the general idea that regulatory action should be taken even when harm cannot be established, and indeed even when it is highly speculative. (Hahn and Sunstein, 2005: 1).

While the legal need for elucidation of the meaning of the precautionary principle must ultimately force the issue of definition, the reality remains that for the time being, a diffuse, though significant political and legal precautionary pressure exists and the "Rio" version (repeated here for convenience) most closely resembles a coherent form of its legal intent.

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (UN, 1992).

Hahn and Sunstein (2005: 1) paraphrase the intent of the "Rio" precautionary principle as paralleling the proverbial advice "better safe than sorry". Peter Montague, who drafted the Wingspread version concurs, but also claims it means "an ounce of prevention is worth a pound of cure" and "look before you leap" (Montague, 1998). This last is perhaps only a hopeful suggestion, as a precautionary approach can surely involve little leaping. The expression "when in doubt, don't" seems a closer approximation of its intent. In any event, it is clearly agreed to mean that judgment should always err on the side of caution.

The quintessential observation of precaution is that the known is more certain than the unknown. The moral values that precaution entails transform this observation into the belief that stability is more important than change, leading to the view that the retention of old and reliable technology is preferable to adopting technological innovation, along with its risks. Ultimately, the idea of precaution values the avoidance of possible loss over the possibility of gain. Precaution is, therefore, effectively a preserver of a *status quo*. It is not primarily concerned with the evolutionary necessity for continuous renewal, but with the risks of the unknowns associated with it, and in the final analysis, it deals with the problem of unknowns by preventing change.

Peter Saunders and Mae-Wan Ho, in a paper entitled "The Precautionary Principle *is* Scientific" argue that the precautionary principle "...is based on science and it generally requires that more good science, not less, be undertaken so that sweeping assurances of safety can be replaced by *solid evidence*" (emphasis added) (Saunders and Ho, 2003). This short extract brings into focus the central problem of the precautionary principle - which is its inherent subjectivity and consequent absence of decisiveness.

The question of what level of evidence constitutes "solid evidence" is an entirely individual judgment. If the opinion of these authors about the solidity of existing scientific evidence regarding the safety of GMOs that is documented earlier in their paper is any measure, the bar can be set impossibly high. Although a veritable army of profoundly competent and eminently qualified scientific specialists have repeatedly demonstrated and explained, over many, many years, that the safety of high-integrity GM technology is based on solid scientific evidence, the authors insist that this is not good enough. The precautionary principle requires, they write, "... that we should not press ahead with commercial crops until we have carried out the research necessary to establish that the technology we are using is safe" (Saunders and Ho, 2003).

The claim that the precautionary principle is compatible with science indicates either a misunderstanding of science or a misreading of the precautionary principle or both. Far from being based upon the same precepts as science and having the potential to enhance it by raising the bar of scientific standards, the precautionary principle (interpreted at face value) betrays an ignorance of the working of science in its demand for the impossible – full scientific certainty.

The pivotal logic of science is that strong empirical evidence supported by a theory amounts to useful power to predict. In essence, the underlying measure of this power is the *frequency* with which empirical observations accord with the theory. However, the power to predict can never be absolute, because the number of potential trials is infinite and conditions may vary unforeseeably. The consequence of this is that science is inherently probabilistic and is conceived and expressed in probabilistic terms. It can never, properly, be expressed as a certainty. One of the practical values of this arrangement is that, interpreted intelligently, it functions as a built in precautionary framework, imposing mathematical perspective and balance.

Consequently, when Saunders and Ho describe the meaning of the precautionary principle as the "obviously sensible" notion that "...we should not go ahead with a new technology, or persist with an old one, unless we are convinced it is safe" (Saunders and Ho, 2003:1) it would normally be presumed that scientific probability is the instrument of convincement that they have in mind. However, uncertainty is inherent to the probabilistic condition, which means that no matter what quantity or quality of evidence is produced, fastidious critics (such as Saunders and Ho) can always point out, quite correctly, that it might be wrong:

> We are often told that GM foods must be safe because Americans have been eating them for years. But if there have been harmful effects, how would we know? ... there is no control group. If all Americans are eating GM foods, none but the most immediate harmful effects are likely to be recognised. (Saunders and Ho, 2003: 3)

Therefore, the as yet unanswered challenge for serious proponents of precaution, such as Saunders and Ho, remains to provide the world with a precise, objective standard of convincement (other than ordinary scientific probability, which is clearly not convincing enough). This effectively means explaining exactly what principle, or factor of decision, actually operates when the precautionary principle is implemented.

In an analysis of the difficulties of usefully applying the precautionary principle, Hahn and Sunstein (2005: 1-3) point out various dilemmas associated with attempts to formulate policy on the premise of maximum safety:

> Risks, sometimes unforeseen, can arise from action as well as from inaction ... [and] reducing risk in one policy domain (say, the environment) could increase risks in another (say, defence) – especially when resources are scarce. ... regulation might well deprive society of significant benefits, and hence produce serious harms that would otherwise not occur. In some cases, regulation eliminates the benefits of a process or activity, and thus causes preventable deaths. If this is so, then regulation is hardly precautionary; indeed it violates the precautionary principle. (Hahn and Sunstein 2005: 2-3).

Citing such examples as the various risks associated with differing forms of power generation, GM foods and trace-level water contaminants, they question the helpfulness of the precautionary principle to regulators. Another example given concerns the US EPA's blanket ban on asbestos. This precautionary measure was overturned in a federal court because the EPA had not evaluated the harmful effects of alternative products, some of which were known carcinogens likely to decrease workplace safety (Hahn and Sunstein 2005: 3). Hahn and Sunstein's summary of the regulatory impact of precaution is not encouraging: "The most general point is that the precautionary principle is frequently paralysing: it can stand as an obstacle to regulation and non-regulation, and to everything in between" (Hahn and Sunstein 2005: 5).

The authors also criticise the selective application of precaution, which is usually used to target new rather than old risks and sensational rather than subtle risks. They conclude that a general necessity exists to consider the negative impacts of technological costs in the context of the positive impact of technological benefits (Hahn and Sunstein 2005: 6). They argue that the purpose of cost/benefit analysis is not to place regulators in "an arithmetic straightjacket", but to provide "the foundation of a principled approach for making difficult decisions" (Hahn and Sunstein 2005: 7).

Aynsley Kellow acknowledges the reassuring plausibility of the "Rio" precautionary principle when he describes its superficial meaning as "commonsense", but he also draws attention to its incapacity to "be operationalised". He argues that it is necessary to "add meaning to the terms serious, irreversible, damage and cost-effective, and decide what level of uncertainty we are prepared to accept as a basis for action" (Kellow, 2002: 124). It is scarcely prudent, he points out, to "take regulatory action on the basis of no evidence, or non-peer-reviewed science, or even a handful of scientific papers" (Kellow, 2002: 124).

Kellow also identifies as a fallacy the implication that conventional science-based regulatory approaches somehow lack prudence. Citing the history of tobacco regulation, he argues that there is no reason to suppose that science-based regulation is inimical to the concept of balanced precaution. Regulatory measures against tobacco were introduced "long before we had identified precise mechanisms of causation ... on the basis of good peer-reviewed science which indicated a problem over thirty years ago" (Kellow, 2002: 124).

Neither is there anything to suggest that precaution is necessarily the foremost priority of communities with respect to issues of health and the environment or the development and adoption of new technology. The example of motor vehicles demonstrates that as long as the benefits derived from use of a technology are sufficiently valued by a society, it may be prepared to tolerate even very significant costs (Kellow, 2002: 124-5).

Alston Chase is critical of the term "Precautionary Principle" itself, which quite wrongly "suggests that public policy decisions based on it are made objectively" (Chase, 1997: 1). More generally he dismisses the thinking behind its conception as facile, regarding attempts to formulate generally applicable theories or simple rules for decision-making as naïve (Chase, 1997: 3). Making a decision by its nature involves incomplete knowledge, and bridging the knowledge gap is inevitably a matter of making projections and assumptions about the future. Consequently, decision is largely about interpretation and opinion and is no less subjective than the assumptions of the person making it (Chase, 1997: 4). Thus, for the precautionary principle to have any effective function at all, he argues, it must incorporate subjective values, which he says are politically "green".

Chase's more fundamental position is that the bedrock of "green" values, the integrity of which is generally accepted without question, is seriously problematic. The environmentalist concept that all the organisms in a system are interdependent and indispensable, and exist in a stable, balanced or somehow coordinated "natural" state is, according to Chase, simply not supported by observation or reason. Environments are rather crucibles of life where relentless environmental pressures and random, sometimes extreme events compel the life forms within them to continuously adapt in order to survive:

> biological systems are constantly assaulted by disturbances and as evolutionary change produces an incessant stream of unique conditions, no single state can be either "healthy" or "unhealthy". … Random disturbance, not permanence or order, governs nature. Left alone, biological communities do not tend toward equilibrium, but lurch wildly, propelled by rapid shifts in species composition, climate and other conditions.
>
> The Precautionary Principle, in sum presupposes the nonsensical notion of the health of nature, which in turn is derived from the mistaken concept of the self-regulating ecosystem. Thus this decision-making rule seeks to bring about conditions that never existed, will never exist and never could exist. (Chase, 1997: 5).

The "common characteristic" to be found among cases of the application of the precautionary principle, writes Chase, is the avoidance of interventions in nature and its processes, but such precautionary regulation in the US has resulted in unwanted environmental outcomes. In Yellowstone Park and the Pacific Northwest forests, a regime of natural self-management of the environment replaced scientifically based management on ideological grounds, but has led to severe environmental degradation, catastrophic fires and in some cases the permanent loss of natural resources (Chase, 1997: 6-7).

Chase argues that precaution is presumptuous and that a Precautionary Principle preempting scientific analysis "is not prudential at all" because it encourages us "to leap before we look [and to] jump to conclusions" (Chase, 1997: 7-8). Consequently, he asserts, far from bringing enlightenment or common sense to regulation of the environment, a precautionary approach is frequently the "worst possible one we could choose" (Chase, 1997:6).

Summary

The "Rio Principle" nominates "lack of full scientific certainty" as the single precondition necessary for mandatory precautionary action to be taken in the face of threats to biosafety. Thus, from a practical, political viewpoint, if its authority is accepted, proponents need only point out the (inevitable) existence of scientific uncertainty, in order to implement it. By its ordinary operation, it therefore biases regulatory activity against the conclusions of science and the possibility of balanced assessment. In consequence, its adoption must also skew administrative procedure *against* the orderly management of innovation and by this means may prevent the free choice of socially advantageous technologies.

It may be concluded from this discussion that four major difficulties appear to be associated with the use of the Precautionary Principle as a regulatory device. Firstly, it is not in any sense a principle. It is not a discriminatory mechanism so it has no value as a decisive instrument. Secondly, it may nonetheless be applied as a principle, displacing scientific analysis and objective understanding, in regulatory decision-making processes. Thirdly, because it acts to neutralise unsubstantiated problems, it can neither anticipate nor stimulate solutions through technological advancement. Finally, it is by its nature and operation biased against innovation.

In consequence, it could be expected that the application of precaution as a primary regulatory instrument would lead to: decisions that are inconsistent with scientific and economic logic, a low frequency of acceptance of regulatory outcomes, disruption of the research agenda, and rundown of affected industries. The remainder of this thesis considers the cases of the four GM crop varieties under consideration and comparatively evaluates the performance of two industries where science has determined GM outcomes and two where precautionary policy has prevailed.

Chapter 4.

THE CASE OF GENETICALLY MODIFIED COTTON

Although cotton has a long and chequered history in Australia, this important and ancient crop[1] is now the basis of one of the handful of great Australian rural industries that are capable of exporting over a billion dollars worth of produce annually[2]. The Australian cotton industry has expanded enormously

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[1] The original root of the word "cotton" is the Arabic word "qutun", which refers to fine textiles. During the Middle Ages the word "cotton" was applied in this sense, as a noun, to fine (usually woollen) fabrics and, as a verb, to the operation of raising the nap of textiles. Its modern meaning is of relatively recent coinage (Cotton Australia, 2006: 16; Macquarie Dictionary, 1991: 405). Cotton cloth dating from 2,500 BC has been retrieved from caves in Mexico, and there is evidence that cotton was cultivated, spun and woven in the Indus Valley in Pakistan 500 years earlier (Cotton Australia, 2006: 15; OGTR, 2002:3).

Soldiers from the army of Alexander the Great took cotton goods back to Europe around 300 BC, after the Persian Empire was conquered and Arab traders of the 1st Century AD took muslin and calico to Italy and Spain. In the Ninth Century the Moors introduced cotton as a crop to Spain and by 1500 knowledge of cotton had become general around the world (Cotton Australia, 2006: 15).

[2] Australia grows some 3% of all cotton, producing an average of over 3 million bales annually, but only about 4% of the national crop is used domestically. With a value averaging around A$1.5 billion, Australian cotton exports are the world's third largest after the USA and Uzbekistan and account for 10% to 20% of international cotton trade (Agrifood Awareness, 2004: 2; Cotton Australia, 2006: 13, 18; Cotton Yearbook, 2006:49; The Australian Cottongrower, June/July 2003: 38). Between 1995/1996 and 2000/2001, cotton constituted an average of 1.6% of total Australian goods exported (King, 2001: 15), and was the fourth most valuable agricultural export after wheat, beef and wool. Cotton was the thirteenth most valuable of all Australian goods exports during that period. Cotton exports were of slightly less value than natural gas exports, of equivalent value to total alcoholic beverage exports and of greater value than milk/cream exports (King, 2001: 15). The cotton

over the last half century in spite of continual criticism of its environmental record[3]. The political issues of chemical contamination, heavy water consumption and to a lesser extent genetic modification have all, in their time threatened its existence. In respect of these criticisms, the industry has managed to offset the political deficit of its environmental image with the political credit of its successes and it has vigorously pursued strong growth

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industry earns approximately one in every twenty dollars directly derived from crops grown in Australia (ABS, 2005: 4).

[3] Cottonseed was brought to Australia from England with the First Fleet in 1788 and small trials were planted as regions north of Sydney were settled (Constable, 2004:1; Queensland Cotton, 2007). The first small shipment of raw cotton to England consisted of three bags and occurred in 1830 (Cotton Australia, 2006: 17). It was grown successfully in tropical Queensland from 1840 and remained that state's most important agricultural crop for some time (Moppett, 1992: Queensland Cotton, 2007). During the American Civil War (1861-1865), Australian growers temporarily supplied British textile manufacturers (Constable, 2004:1; Queensland Cotton, 2007). Production peaked in 1871 at 5,204 bales and thereafter declined due to "poor prices ... irregular rainfall ... transport costs and transport time delays" (Queensland Cotton, 2007). Cotton was introduced to the Northern Territory in 1882, but failed due to overwhelming damage from insect pests (OGTR, 2002:3).

The Australian industry was revived after World War I when the boll weevil devastated US production (Moppett, 1992). Encouragement and investment by British textile organisations led to rapid growth in Australian cotton production. The Australian Cotton Growing Association (Queensland) Limited, an industry management and marketing body, was instituted in 1921 (Moppett, 1992; Queensland Cotton, 2007). By 1934 total Australian cotton production had reached 17,000 bales, but by 1954 the industry was again "all but non-existent" (Cotton Australia, 2006: 17). Cotton cultivation had begun in the Kimberley's in Western Australia in 1947, but again was unsuccessful due to insect damage (OGTR, 2002: 3). Production was briefly re-established there in the 1960s and the early 1970s during the developmental years of the Ord River Irrigation scheme, but failed again for the same reason (Cotton Australia, 2006: 17).

and the improvement of its environmental credentials. The substantial value of cotton as an export and its central importance in its growing region has ensured ongoing political support for the industry[4].

At the farm level, it has worked to overcome the obstacles to its survival through a highly organised commitment to overcoming the practical limitations to economic and environmental sustainability. Agronomic and downstream problems have been identified and targeted with well-funded research, and the general willingness of its members to rapidly adopt the ensuing technological innovations is a prominent feature of the industry.
To date, the Australian cotton industry has successfully addressed the difficulties that have confronted it and maintained a competitive edge in an increasingly demanding world market. The general willingness to adopt GM varieties in 1996 typifies the progressive attitude that has set the cotton industry apart from the rest of Australian agriculture and established it as a

[4] The modern Australian cotton industry dates from 1961 and owes its genesis to "the search to find uses for water from the newly constructed Keepit Dam on the Namoi River in northern New South Wales," according to water resources analyst Peter Crabb, in a report prepared for Environment Australia in 1996 (Crabb, 1996: 79). In 1961, two Californians, with expertise in growing irrigated cotton, produced 96 bales from 26 ha (65 acres) near Wee Waa (Crabb, 1996: 79; Moppett, 1992). As Australia was importing cotton, the Commonwealth introduced a bounty in 1963 to stimulate production and in that year plantings extended into the Macquarie Valley (Constable, 2004: 1; Moppett, 1992). Subsequently, the industry was able to take advantage of the Burrendong Dam's completion in 1968 before further expansion into the Bourke area, the Gwydir and MacIntyre valleys, southern Queensland, south along the Darling and into southern NSW (Crabb, 1996: 79; Moppett, 1992).

strong and determined sector. It appears likely that domestic and international pressures on the industry will increase in the immediate future, so continued prosperity will remain contingent upon maintenance of a resourceful and adaptive approach

Cotton is naturally a perennial shrub that may grow to a height of 3.5 metres[5], but in commercial agriculture it is grown as an annual reaching only 1.2 - 1.5 metres It is grown as a summer crop, that is, it is sown in spring and

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[5] The cotton plant is a member of the Hibiscus family and belongs to the genus *Gossypium,* which consists of around fifty species (Cotton Australia, 2006: 2; OGTR, 2002:3). The area of its ultimate origin is uncertain, but "the primary centres of diversity for the genus" are Mexico, N.E. Africa/Arabia and Australia. DNA data suggests that the genus arose 10 – 20 million years ago (OGTR, 2002: 3). Cotton is the world's most widely grown plant fibre crop, comprises 39% of the total fibre market and is cultivated in some 65 countries (AFAA, 2004b; Cotton Australia, 2006: 2; OGTR, 2002: 4). It is grown warm temperate to tropical regions including southern and western USA, India and the Middle East, China, Central and South America, western and southern Africa and Australia (OGTR, 2002: 4; Rabobank, 2005: 3-4)..

The 4 species of cotton are: *Gossypium hirsutum, G. barbadense, G. arboreum and G. herbaceum,* which originated respectively in Central America, South America, North Africa and South Asia (Cotton Australia, 2006: 16; OGTR, 2002:3). *G. hirsutum* comprises 90% of world plantings and *G. barbadense* (known as long-staple cotton) most of the remainder. In Australia, *G. hirsutum* accounts for almost the entire crop, although a little *G. barbadense* is also grown. *G. arboreum* and *G. herbaceum* are grown in Asia (OGTR, 2002:3). These species were all independently selected, propagated and cultivated in places as diverse as Mexico, South America, Africa, Arabia, Pakistan and China in ancient times (Cotton Australia, 2006: 15; OGTR, 2002:3).

harvested in the autumn and the plant is destroyed at or after harvest[6] (Cotton Australia, 2006: 2, 6; OGTR, 2002: 5). The plant thrives in warm to hot climates of low humidity and high sunshine hours[7], with at least 175 days (6 months) that are free of frost (Cotton Australia, 2006: 2, 12). Cotton requires a constant soil temperature of at least 14 degrees Celsius at 10cm depth as well as adequate moisture in order to germinate and grow reliably[8]. Typically, these conditions occur in late September in Northern NSW and a month earlier in Central Queensland. (OGTR, 2002: 5-6).

[6] The calendar of a typical cotton farming operation involves soil preparation in August/September, sowing the crop in September/October, monitoring and managing the crop's growth (water, weeds, disease, nutrition) November – February, and harvesting, ginning and pressing the cotton when it is mature, sometime between March and May. Winter crops may afterwards be sown (Cotton Australia, 2006: 6; OGTR, 2002: 5).

[7] Within limits, growth rates and yields of cotton correlate positively with both temperature and sunshine hours (Cotton Australia, 2006: 6), while humidity and cool, wet weather, which are conducive to fungal diseases, inhibit production (OGTR, 2002: 14). Consequently, a hot, sunny and dry climate with adequate available water provides optimum conditions for the crop.

[8] In Australia, the existing cotton-producing region is located more or less centrally in the arable eastern portion of the country, in valleys of the Darling River catchment. While many areas of Australia fall within the crop's climatic parameters, the industry has evolved and is currently "concentrated in Northern NSW and Southern Queensland". It ranges from Hillston (NSW) in the south to Emerald (QLD) in the north and extends to the west as far as Bourke (NSW). Around two thirds of Australian cotton (63% in 2005/2006) is grown in central/northern NSW while the remaining third (37% in 2005/2006) is grown in southern Queensland (Cotton Australia, 2006: 5; Cotton Yearbook, 2006:42).

Research and experience has demonstrated that a combination of minimum tillage and crop rotation with wheat (2 years cotton, 1 year wheat) is advantageous for soil structure, nutrient status and water-use efficiency, as well as providing a disease break for *Verticillium* wilt, a serious and widespread fungal disease of cotton (Constable, 2004: 2, 3; OGTR, 2002: 14). The identification of these factors and the development of appropriate soil management practices have been described by prominent Australian cotton researcher, Dr Greg Constable, as comprising "a key element of yield progress in the cotton industry" (Constable, 2004: 2).

Attempts to introduce cotton to various other parts of Australia have failed in the past, but there seems no shortage of interest in extending and diversifying its agricultural base[9]. The emergence of water as a major political issue raises the possibility that significant constraints may be placed upon the cotton industry in the northern parts of the Murray-Darling basin and the short-term ability of technological solutions to compensate for heavy cuts to irrigation allocations is limited. If the cotton industry is to grow - perhaps even if it is to survive at all, it seems fairly clear that it must be grown in new areas.

[9] Cotton was grown in the north of Western Australia as recently as the early 1970s (Cotton Australia, 2006, 17) and ten years before that was successfully grown as far south as Swan Hill in northwest Victoria. Some interest has been shown by the Bayer corporation, in the revival of a cotton industry on the Murray, in the Swan Hill area and also in South Australia (Bayer, 2004b; Lush, 2004).

Consistent with this view, in 2002 the OGTR reported that GM cotton trials were being undertaken in Richmond, North Queensland, in Western Australia and in the Northern Territory (OGTR, 2002: 5).

In 2005, the OGTR granted Bayer a licence to conduct trials of its "Liberty Link" group of GM cotton varieties in any agronomically suitable areas of the five mainland States and the Northern Territory (OGTR, 2005). The undertaking of such trials is subject to permission being granted at State level also. The existence of the licence, however, establishes the point that (in the opinion of Bayer corporation and the OGTR at least) a significantly extended portion of rural Australia could realistically consider adding cotton to its range of crops. Although this development might be interpreted merely as evidence of Bayer's desire to grow its business, it is likely that extension of the cotton industry's geographical base would further many other corporate, government, industry and community interests as well.

About 80% of Australian cotton crops are irrigated, using water supplied by NSW and Queensland irrigation schemes, the remaining "dryland cotton" being reliant upon rainfall for sufficient moisture (Constable, 2004: 1). Although cotton requires low humidity, high temperatures and high solar radiation, "moisture availability is of critical importance" (Crabb, 1996: 79), in order "to maintain growth of the crop and the fibre" (Constable, 2004: 2).

For successful dryland crops, adequate soil water and its replenishment through rainfall at particular stages of plant development are "absolutely essential" (Crabb, 1996: 79). Irrigated crops are dependent upon applied water and grown in expectation of its availability, which can be uncertain. Water allocations are reduced under drought conditions - not infrequently to nil[10] (Constable, 2004: 2).

The existing Australian cotton-growing region is "regularly affected by drought" (Constable, 2004: 2) and the frequency of extended dry conditions is reflected in the variability of annual national production statistics. Research since the 1970s has identified critical stages of crop development and led to the implementation of strategic water-management approaches designed to maximise irrigation efficiency (Constable, 2004: 2). Soil management and structure improvements have significantly improved irrigation efficiency, impacting positively on plant-water relations through increased soil water

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[10] Crop returns from cotton are highly sensitive to seasonal variations in water availability and production levels have been erratic and generally poor in the recent run of dry and very dry years, often being reduced to less than half of those achieved in the better years (Cotton Yearbook, 2006: 40-42). Raw cotton exports for 2002/3 are fairly representative of the years since the turn of the century, with a value of A$1,154m. At the extremes, the figure of A$773 million for 2004/2005 was a little more than a third of that achieved in 2000/2001 when exports were comfortably in excess of the A$2 billion mark. (ABS, 2004:16; Cotton Yearbook, 2006: 42; DAFF, 2004; DFAT, 2005). Cotton exports have not exceeded A$1.5 billion since 2001/2002 (Cotton Yearbook, 2006: 42). The period 1995/1996 to 2000/2001, which includes the years immediately following the 1996 introduction of GM cotton varieties, was a period of strong growth during which the average annual value of cotton exports was A$1.36 billion (King, 2001: 15).

storage capacity and enhanced root exploitation of improved soils (Constable, 2004: 2). Considerable research resources are devoted to the improvement of cotton irrigation technology and practices (Cotton Australia, 2006: 10; Dalton, Raine and Broadfoot, 2001: v).

On the basis of available data, Australian cotton irrigation systems are at least as efficient as any others in the world (Constable, 2004: 2). Research reported by the Cotton Catchment Communities CRC/CSIRO in 2003 showed that, on average, Australia was producing 2.5 kilograms of cotton lint[11] per hectare,

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[11] The material that is directly harvested from the cotton plant (comprised of the dried fruit or bolls) is known as seed cotton and is processed in a cotton gin (corruption of engine) to separate the lint from the seed. The lint is spun into yarn, which may then be knitted, woven or otherwise utilised (OGTR, 2002: 4).

Cotton fibres are formed by the "epidermal cells of the seed coat [which] bears two types of fibres – long lint fibres valued by the textile industry and short, fuzzy fibres, known as linters" (OGTR, 2002: 11). Cotton fibres consist of cellulose coated with a thin layer of wax (Cotton Australia, 2006: 2). The seed recovered after "ginning" retains a coat of linters that are removed and put to various uses. There are first cut and second cut linters. First cut linters are longer and are used for such purposes as furniture and car upholstery, mattresses, bandages, cotton buds, bank notes, X-rays and mops (Cotton australia, 2002: 3; OGTR, 2002: 4-5). Second cut linters are very short and used as a source of cellulose for both chemical and food technology purposes. Their uses in foods include the provision of cellulose for "high dietry fibre products … [and for] thickener … in [products such as] ice cream, salad dressing and toothpaste" (OGTR, 2002:5). Chemically, they are used in the production of "cellulose derivatives such as cellulose acetate, nitrocellulose and a wide range of other compounds" (OGTR, 2002:5).

Delinted seed is the source of cottonseed oil, cotton meal and cotton hulls (OGTR, 2002: 5). However, raw cottonseed contains "anti-nutritional and toxic factors including gossypol and per millimetre of evapotranspiration, compared to 2 kg/ha/mm in California and 0.3-1.3 kg/ha/mm in developing countries (Cotton Australia, 2006:9). The Australian cotton industry's measurable efficiency in water-use has increased by 11% since 1999 (Cotton Australia, 2006: 9).

Table 4.1 below shows official Australian irrigation statistics for several important crops in 2002- 2003. Cotton was second to grazing in "total volume applied" and second to rice in "volume applied per hectare". However, the dollar return per ML of water for cotton, or its economic efficiency, outstrips sugar, rice, livestock and pasture (Cotton Australia, 2006:9). The particularly hot and dry climatic conditions favourable to cotton are conducive to high levels of evapotranspiration, so irrigated crops grown in these environments, including cotton, have a high water requirement.

Table 4.1.

	Cotton	**Rice**	**Sugar Cane**	**Fruit**	**Pasture**	**Grapes**	**Cereals**
Total Water	1,525,502	615,375	1,293,099	659,893	2,826854	588,794	1,001,579
ML/ Ha	6.5	14.1	5.4	4.8	4.0	3.9	2.8

Comparative table of 2002-2003 Australian irrigation water applications by crop, expressed as total megalitres and average megalitres per hectare (Linacre, 2005:5).

cyclopropenoid fatty acids" and may be dangerous "if ingested in excessive quantities" (OGTR, 2002: 17). Cottonseed oil and linters destined for human consumption, therefore, require "extensive processing to remove toxicants" (OGTR, 2002: 17). Although gossypol-free cottonseed meal is approved for human consumption in the USA and is valued as a cheap source of protein in India and Central America, it is not consumed in Australia or New Zealand (OGTR, 2002: 18).

Cotton growing is also highly intensive, demanding significant capital investment in irrigation equipment, water supply, special machinery, "high annual inputs and a high level of management skills" (Crabb, 1996: 79), but is a financially rewarding investment, as "few crops provide a better return for the farmer" (Crabb, 1996: 79). The potential earnings, whether calculated on the basis of economic or water inputs make it an attractive proposition to farmers of the region in comparison to the limited alternatives. The fundamental profitability of cotton underlies the success of the industry in Australia and this basic fact of farming has led to the area sown increasing from around 50,000 ha in 1980 to a peak of over 500,000 ha twenty years later (Cotton Yearbook, 2006: 40; Crabb, 1996: 80).

The present political sensitivity of water use and the prominence of cotton as an irrigated crop have revived public criticism of the cotton industry. Water extractions for the purpose of cotton growing (conducted entirely in the Murray/Darling basin) are, unsurprisingly, higher than for any other single crop (Linacre, 2005: 5). Due to this fact and the very heavy chemical use that was associated with conventional (pre-GM) cotton, the industry is still burdened with "a reputation for excessive use of pesticide and water" (Constable, 2004: 2)[12].

[12] Constable attributes this unflattering and inaccurate image, at least in part, to open acknowledgement of these problems by the industry and "inaccurate reporting in our media" (Constable, 2004: 2).

The essential level of dependence of cotton upon water is difficult to unequivocally establish (Reid, 2006) - there is a dearth of relevant empirical evidence to support public argument. However, the availability of GM early maturing varieties of cotton has led to the recent rise of a cotton industry in Southern Kansas, USA (Kansas inc., 2005: 2), which (at 37 to 40 degrees North) is located on a similar latitude to Southern Victoria. The experience of cotton growers there is that cotton has a moderate demand for water:

> … time has shown us that there are many other advantages in choosing to grow cotton. For one, cotton does not need a great amount of water and is very drought tolerant. A profitable crop only needs about 8-9 inches of irrigated water compared to 15-19 inches for corn. This is especially important in western Kansas where water has become an important issue. A significant switch to cotton over other more water-intensive crops would drastically reduce the drain of pumping out of Ogallala Aquifer.
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> Also because cotton does not need much water it is an excellent dryland crop. This is especially true in western areas of the state where farmers have a difficult time producing other dryland crops. One crop in particular that cotton could be a good substitute for is soybeans. In the western part of the state it is difficult to consistently produce non-irrigated soybean crops, so to be able to produce a profitable crop like cotton in its place would be a great benefit to the region. (Kansas Inc., 2005: 3).

The Kansas primary industry view that cotton, as a "drought tolerant" crop, might form part of a solution to emerging water shortage sharply contrasts with the popular Australian view of cotton. Nine inches of irrigation is less than 2.3 ML/ha, but differing conditions, options and practices mean that experiences in Kansas cannot be directly related to Australia, where 6.5 ML/ha was used in 2002-2003. Nonetheless, it would seem that the empirical basis of Australian public perceptions about cotton requires clarification.

Cotton consumes the greatest volume of irrigation water after "pasture for grazing" and the most "irrigation water per hectare" after rice (Linacre, 2005: 5), but it also comprises a large and valuable primary industry and the superlatives do not necessarily denote fault. As cotton is the fourth largest Australian rural export after beef, wheat and wool, the sector is virtually bound to be the heaviest consumer of water, as beef, wheat and wool production involve far less dependence upon irrigation. In respect of all irrigated crops, variability of water requirement is inevitable and the capacity of a crop to convert water into income must be considered in its evaluation. According to Bruce Finney of the CRDC, the industry achieves on-farm efficiency gains of 2.5% to 3.0% annually and lint yield per megalitre of water doubled from one bale/ML to two bales/ML between 1996 and 2006 (Finney, 2006).

Water demand of the cotton plant is an established area of GM research, and Monsanto Australia already has a variety licensed and under trial that has been modified for "water use efficiency" (OGTR, 2007). Other modifications for environmental tolerance would have the potential capacity to extend the range of soils and locations where it is possible to grow cotton, so reducing pressure on the Murray-Darling water resource. The Kansas example demonstrates the feasibility of such options:

> Kansas has only recently become receptive to growing cotton because of new genetically engineered varieties. Cotton requires a lot of heat units to grow and Kansas does not stay hot enough, long enough to support normal cotton plants. With the development of early maturing varieties cotton can be harvested during Kansas' shorter summers. (Kansas Inc., 2005: 2).

The environmental movement has long opposed the cotton industry's access to water, but withholding water from cotton farmers makes little sense unless it is to be put to a more profitable use.

The Cotton Economy

As the producer of a "high value commodity", the cotton industry "makes a major contribution to the economies of the growing areas and to the Australian economy as a whole" (Crabb, 1996: 79). Australia has around 1500 cotton growing enterprises, each typically growing 500 to 2000 hectares of cotton annually (Cotton Australia, 2006: 5; DAFF, 2004). Some of these are "very large producing units" (Crabb, 1996: 79) while others are mixed farmers and smaller croppers who include cotton in their crop rotation (Constable, 2004: 2; DAFF, 2004). In excess of 4,000 businesses are directly dependent upon cotton production and some 10,000 people rely on the industry for employment. In the Gwydir, Namoi, Macintyre and Macquarie valleys, cotton accounts for at least 50% of total agricultural activity (Cotton Australia, 2006: 5). A consequence of this is that the broader fortunes and interests of these regions are closely integrated with the health of the cotton industry.

Since most Australian cotton is sold as raw cotton on the international market, the Australian crop is "forward sold" through processing and marketing companies up to three years in advance of sowing (Cotton Australia, 2006: 13). This practice helps to reduce the uncertainty attached to commodity production and is conducive to industry stability and thus to planning and organisation at an industry level.

Contemporary Australian cotton farms are "highly mechanised, capital intensive, technologically sophisticated and require high levels of management expertise" (Cotton CRC, 2005: 3). As the Australian cotton industry, unlike most, does not have access to either low-cost labour or government subsidies, a competitive advantage can only be maintained by continuously seeking a technological edge. Consequently, the industry is consciously progressive and strongly committed to an ongoing program of research that is supported with a $30 million annual budget[13] (Cotton Australia, 2006: 10). Thanks to its advanced technology, Australia is one of

[13] Growers directly contribute $2.25 per 227 kg bale ($10/tonne) through a compulsory research levy, which is matched by the Commonwealth Government to fund the Cotton Research and Development Corporation (CRDC), "the major industry research funding organisation" (Cotton Yearbook, 2006: 108). The 2006 Cotton Yearbook lists 94 ongoing research projects enjoying the support of the CRDC (Cotton Yearbook, 2006: 108-111).

the world's lowest-cost producer nations, along with China, Brazil and Pakistan, which depend on cheap labour. The US and Israel are extreme high-cost producers (Cotton Australia, 2006: 12).

Net downward pressure on the international cotton market is a function of separate pressures affecting supply and demand. Constant improvements in productivity tend to increase the availability of raw cotton and global production in 2004/5 was 26% higher than in 2003/4. At the same time, the trend in consumption is unfavourable and competition from synthetic fibres caused "cotton's share of the world fibre market [to fall] from 50% in 1986 to 9% in 2004" (Cotton Australia, 2006: 13). Expansion of the global crop in recent years is largely due to large production increases in China and Brazil (Cotton Australia, 2006: 12). The direct consequence of these conditions for a commodity producer such as Australia, with little power to directly influence

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Sustainability programs are ranked highly in importance and account for 50% of the CRDC's budget (Cotton Australia, 2006: 10).

The Cotton Catchment Communities Cooperative Research Centre (CCC CRC) is a "research cooperative body set up by the Federal Government ... which has committed $26.5 million ... supported by pledges of $36.8 million in cash and $74.8 million in-kind from CRC partners" (DPI NSW, 2005). The partners include State departments of primary industry, universities, other research organisations and some industry interests. It has five research programs – farm, catchment, community, product and adoption. CCC CRC has ensured funding until 2012 and its aim is "to undertake a multi-disciplinary and cutting edge research program to develop and have cotton and grain growers adopt world's best practice in environmental and catchment management" (DPI NSW, 2005).

prices, is a constant necessity to minimise costs and to maximise yields and quality.

Although it is the world's second largest producer of cotton[14], the US industry is also the most heavily subsidised, the US government providing more than half of US cotton grower receipts (Cotton Australia, 2006: 14). Since their share of total production is so large, this has a depressing effect on international prices and on production levels in unsubsidised exporting nations such as Australia. If the US subsidies were removed, according to the CRDC, total Australian revenue would increase by $177 million overall and individual farm returns would increase by 19% (Cotton Australia, 2006: 14).

Since Australia normally no longer protects or subsidises primary industry, the main strategy of the cotton industry has been to increase productivity and quality through the development and adoption of better technologies and practices. "Critical to the success of the Australian exports are price and quality performance of the fibre combined with low contamination levels and timeliness in delivery to market" (Turco, 2003: 38).

[14] Almost half of the world's cotton is produced by the US and China. China grows about 25% of all cotton and is also the world's largest importer (18.5 million bales in 2005-2006). The US grows about 20% of total cotton and, with the decline of its own textile sector, has become the world's biggest exporter, selling over 16 million bales on the international market in 2004-2005 (Cotton Australia, 2006: 12-14; Cotton Yearbook, 2006: 49-50; The Australian Cottongrower, June/July 2003: 38).

Between 1994 and the 2004/2005 season, Australia increased its average yield per hectare by 50% (Cotton Australia, 2006: 5) while achieving considerable reductions in input costs through technological advances, including genetic engineering (Cotton Australia, 2006: 11). The industry also increased the area planted by 50% over this period. Australia's 2004/2005 average yield was 2,088.4 kg/ha, the highest ever recorded by any country, compared to 1,571kg/ha for the second-highest (Syria) and a world average of only 732 kg/ha (Cotton Australia, 2006: 5). In 2005-2006, Australia's average yield of 1783 kg/ha was close to double that of the US industry's 931 kg/ha (Cotton Yearbook, 2006: 46).

The second area of advantage that the Australian industry has been able to develop is that of quality. The imperative for the Australian industry has been to position itself as a "preferred supply base for cost efficient, quality specific and reliable supply of lint" (Turco, 2003: 38). Around 70% of all cotton produced is of lesser quality than the vast bulk of the Australian crop which is classified as "high-medium" or "fine" quality. "A large proportion" of coarser cottons is produced "in countries such as India, Brazil, China and Pakistan – thereby reducing the impact they have on the Australian marketing position", while only about 25% of US cotton provides "strong competition" for the Australian product (Turco, 2003: 38).

As a producer of high-medium to fine quality cotton, Australia "rarely competes for a share of the market against some of the bigger producing nations … as there is rarely an oversupply of cotton of this type" (Turco, 2003: 38). Australia has, therefore, established itself as a significant, competitive and committed participant in the international cotton trade.

Pests, Insecticides and Genetic Modification

The OGTR records that in excess of "1326 species of insect have been reported in commercial cotton fields worldwide but only a small proportion are pests" (OGTR, 2002: 12). The dominant variety cultivated in Australia, *Gossypium hirsutum* is subject to attack from 30 pests, the most economically significant of which are the larvae of two species of moth *Helicoverpa armigera,* and *Helicoverpa punctigera,* as well as *Tetranychus urticae*, the two-spotted spider mite (DPI&F, 2005:1; OGTR, 2002: 12). *T. ludeni* and *T. lambi* are less frequently encountered spider mite pests[15]. Aphids, thrips,

[15] Spider mites, the third major pest of significance to cotton, are of some relevance to the subject of this study, due to the significant exacerbating effect of broad-spectrum sprays upon their incidence (CCC CRC, 2006a: OGTR, 2002: 13) and the consequent remedial effect of GM technology on spider mite outbreaks. Spider mites are sap-sucking arachnids that live on the undersides of leaves, cause "bronzing, reddening and eventual desiccation of the leaf" (OGTR, 2002: 13) and can also act as disease vectors.

Predator activity early in the season is important in containing the size of mite populations (CCC CRC, 2006a). Predator species include ladybirds, thrips, lacewings, damsel bugs and big-eyed bugs (CCC CRC, 2006a: OGTR, 2002: 13). Mites are normally a late-season pest and can "significantly affect both yield and quality of cotton" (OGTR, 2002: 13)). A rapid life cycle of only 7 to 14 days in summer means that population build up can be very swift (CCC CRC, 2006a).

mirids and white fly are generally considered to be minor pests although all have the potential to cause serious economic damage under conducive conditions (Cotton Australia, 2006: 8; OGTR, 2002: 13).

The common names of the two *Helicoverpa* species are, respectively, "the cotton bollworm", a widespread pest that attacks many agricultural and domestic crops around the world and "the native budworm", which is endemic to Australia and attacks a wide range of crops (OGTR, 2002: 12-13). Both species are occasionally referred to by their former generic name of *Heliothis*. A CSIRO pamphlet describes *Helicoverpa* caterpillars as "the main insect pest of cotton ...[that] have the capacity to completely destroy a cotton crop if not managed" (CSIRO, 2005: 1).

The life cycle of a generation of *Helicoverpa* typically takes 42 days, from egg laying to egg laying, for both species. This allows 4 or 5 life cycles to occur during each 6 month cotton season (CCC CRC, 2006a). The caterpillars destroy the young leaves, buds and fruit of the cotton plant, particularly favouring reproductive tissue. They are capable of killing

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Mites in cotton provide an example of the now classic phenomenon of pest outbreaks arising from the use of broad-spectrum chemical control agents. The use of these chemicals to suppress pests such as *Helicoverpa* or green mirids (*Creontiades dilutes*) can cause destruction of the predator insect communities that limit the growth of mite populations, while leaving the mites themselves unaffected (CCC CRC, 2006a; OGTR, 2002: 13). The consequence can be unexpected surges in mite numbers resulting in substantial crop damage (CCC CRC, 2006a).

seedlings or boring in to maturing bolls and consuming their contents. Further, secondary damage may arise from opportunistic fungal infections at the sites of caterpillar damage. (CCC CRC, 2006a; OGTR, 2002" 12-13). Significant economic loss can result from quite low population densities, so awareness and control of insect numbers is critical. Under some circumstances, an average of as few as two caterpillars per metre of row may justify spraying an entire crop (CCC CRC, 2006a).

In the case of the bollworm (*H. armigera*), the last generation of the season overwinters in the ground near the plant as pupae in a state of suspended development known as diapause (OGTR, 2002" 13). They re-emerge as adult moths in spring and after mating lay their eggs on a suitable host plant such as winter crops of wheat, grain, legumes or weeds before subsequent, bourgeoning generations infest cotton and other summer crops, including sunflower, maize and summer legumes. (CCC CRC, 2006a; OGTR, 2002" 12-13).

As relatively low numbers tend to survive the winter, 1 or 2 generations are usually required to increase the population to a seriously damaging level. Consequently *H. armigera* is regarded as a mid-season to late-season pest. Post harvest cultivation of cotton fields, which kills the pupae, is one of the most effective non-chemical means of controlling *H. armigera* and of inhibiting the development of insecticide resistance (CCC CRC, 2006a; OGTR, 2002" 13).

The native budworm (*H. punctgera*) has almost identical morphology to *H. armigera* and to the untrained eye the two species are indistinguishable at every stage of development. It is a migratory insect that lives and breeds on flowering plants in the semi-arid interior of the continent during the winter months (CCC CRC, 2006a; OGTR, 2002" 13). When the weather warms in spring, its host plants deteriorate and large numbers of adult *H. punctgera* migrate *en masse* to the arable areas of Australia. Taking advantage of the "frequent, easterly moving weather fronts" (CCC CRC, 2006a) they can travel with great speed, often covering the vast distances involved (500 to 1500 km is not unusual) in as few as one or two nights (CCC CRC, 2006a; OGTR, 2002" 13).

Arriving in the Australian cotton growing region early in the spring, 2 to 4 weeks before the emergence of the overwintering *H. armigera*, the first generation of larvae feeds on pasture, weeds and early crops such as linseed, rapeseed and legumes (CCC CRC, 2006a; OGTR, 2002" 13). The next and subsequent generations target rapidly growing crops such as cotton and oilseeds. *H. punctigera* is regarded as an early season cotton pest and tends not to persist into the more mature stages of the crop. By the end of the season, its numbers are reduced to a fraction of the peak population and very few individuals enter diapause and overwinter locally (CCC CRC, 2006a; OGTR, 2002" 13).

The differences between the behaviour patterns of the two species have great relevance for cotton growers. The staggered population development over the growing season means that *Helicoverpa* control is a season long concern and that under conventional management the appropriate species had to be targeted. In practice, this meant that growers needed to devote much of their time and other resources to continual crop-monitoring and the maintenance of spray coverage. *H. armigera's* habit of remaining in a particular cropping location as a permanent population also meant that under intensive, chemical agriculture, the frequent exposure of whole populations to insecticides led to rapid selection for resistance (CCC CRC, 2006a).

The over-winter survival of *H. armigera* individuals through diapause in the soil of cotton fields is central to the carryover of acquired chemical resistance from year to year and its permanent entrenchment in the population (CCC CRC, 2006a). The species' ability to rapidly incorporate resistance into its genome renders the strategy of chemical control unsustainable without an infinite range of suitable chemicals. The swift evolution of *Helicoverpa* resistance to DDT then to dieldrin and its successors, led to the abandonment of the very high yielding cotton production project on the Ord River in 1973, after 25 years of research and investment (AAS, 2001; Cotton Australia, 2006, 17; HCWA, 2001: 8-10; Willacy, 2006).

For the next 23 years the inability of agrichemical technology to remain abreast of *Helicoverpa* resistance increasingly threatened the viability of the entire Australian cotton industry (Peacock, 2003, 1, 3; Perry, 2004, 1). In the case of the relatively recently developed synthetic pyrethroids, for example, the OGTR reports that 80% to 90% of individuals in any given population of *H. armigera* are likely to have inherited a resistant genetic makeup (OGTR, 2002" 12).

H. punctigera, on the other hand, with its migratory habit and its tendency to overwinter on weeds in the outback has exhibited a far less marked tendency to develop chemical resistance (CCC CRC, 2006a; OGTR, 2002" 13). Although, nonetheless, a very challenging pest, the "constant influx of *H. punctigera* immigrants to the cotton growing areas is thought to be responsible for the lack of development of resistance to chemical pesticides in this species"[16] (OGTR, 2002" 13).

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[16] A further consequence of the outback overwintering habit of *H. punctigera* is that the number of migrants in any particular year is determined by the conditions prevailing in the autumn-winter season in the interior. In a good year numbers are likely to be high, while the reverse applies in dry years and knowledge of these conditions can assist growers in their pest management tactics (CCC CRC, 2006a).

Until 1996, the major consequence of the biology of *Helicoverpa* for Australian cotton growers was that control of these pests was reliant upon informed and careful management including chemical rotation, and constant advances in chemical technology. Dependence on chemical control had the disadvantages of high crop inputs, various biosafety issues and community tensions.

The outlay on insecticides and associated expenses was a significant cost component that could seriously affect profitability in a difficult year. As a variable cost, dependent upon seasonal conditions, pest control expenses could be an unpredictable threat to budgets and profits. Much cotton spraying was done from the air. Aside from predictable community concerns about conspicuous and continual aerial dissemination of insecticide, the public nuisances of aircraft noise and noxious smells were an ongoing difficulty for cotton growers and residents.

Of far greater political importance was the broader Australian community's unease with heavy chemical use in the context of growing concern about environmental degradation. By the mid 1970s, the cotton industry had the unenviable reputation of being the "dirtiest" sector of Australian primary industry and as time passed, public pressure to reduce chemical use intensified. A 2005 Land & Water Australia case study observes:

> There is no doubt that there was considerable anxiety about the use of pesticides by the Australian cotton industry. This has been associated with perception (amplified by the media) that cotton pesticides might be a cause of leukaemia and other illnesses, particularly in children. Credibility has been gained by cases of fish kills associated with spraying of endosulphan, over which several prosecutions have taken place. As noted by Anthony (1998, p. 13) "The Australian cotton industry, perhaps more than any other agricultural enterprise, has been at the epicentre of tension over agricultural practice. Clearly the use of chemicals and concern for the riverine environment have been key pressure triggers. ...[The] perceptions of an increasingly urbanised community that agricultural practices are harmful are adding greater tension". (LWA, 2005:94)[17].

Irrespective of the level of hazard, the existence of public unease and displeasure over such heavy chemical use by the cotton industry was not

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[17] Land and Water Australia continued:

> At the time when the pesticides program commenced, there was considerable anxiety in cotton growing areas about the use of pesticides and in particular endosulphan. The anxiety may have arisen from perception rather than scientific reality. As observed by Anthony (1998, p. 13), "scientific information generated by the [pesticides] program indicated no major impact of agricultural chemicals on the riverine environment". He further commented on the ability of chemical analyses to detect chemicals of less than one part in 100 billion, and that it is impossible for any human activity to operate at a zero tolerance level. Nevertheless, there would have been a substantial willingness to pay by residents in towns in cotton growing areas for assurance that their health was not at risk from pesticides and that riparian areas were not subject to high levels of pesticide residue. It could be argued that the industry had a responsibility to remove this anxiety, which should have proceeded regardless of the pesticides research (LWA, 2005: 94).

unreasonable. In the course of delivering the 2004 HV McKay Lecture, Richard Roush, Director of IPM at the University California, Davis[18], pointed out that on a worldwide scale, “almost half of total, insecticide used in agriculture is applied to cotton, with roughly half of that used against caterpillars” (Roush, 2004, 2). Furthermore, in a largely unregulated agricultural environment, the gross human risks of chemical use are obvious and easily quantified. Until 1997, when China adopted GM cotton technology, “there were at least 10,000 insecticide poisonings and about 400-1000 deaths per year in Chinese cotton growing areas” (Roush, 2004, 1).

Questions of biosafety, or impact on the biological environment, essentially arise from the toxicity, mobility and persistence of chemical agents. The past heavy use of chemicals in cotton has led to a number of problems, including residues of chemicals such as endosulfan and atrazine in soils, foods and waterways (Constable, 2004: 3; Crabb, 1996: 79). Other substantial biosafety issues related to pesticide use in cotton included direct chemical hazard to operators, other workers and local communities, and damage to non-target insect populations.

Integrated Pest Management (IPM) and Best Management Practice (BMP).

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[18] Since appointed Professor of Land and Food Resources at Melbourne University.

The FAO has defined Integrated Pest Management (IPM) as:

> the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. (Fitt et al, 2004: 2).

In practice this means the adoption of an integrated suite of practices that minimises, but does not necessarily abandon, the use of chemical controls. The intention is to reduce the environmental impact of agriculture without compromising productivity.

The original approach in the cotton industry, adopted in the late 1970s was limited to the introduction of crop-sampling systems and pest thresholds to optimise pesticide use (Fitt et al, 2004: 2). It has now expanded and developed to include the minimisation of chemical applications, the use of pest resistant varieties, the protection and stimulation of beneficial populations, the use of selective and minimally resistant chemicals, the recognition of the "compensatory capacity of the plant" and an array of cultural control practices and tactics (Fitt et al, 2004: 2).

The main principles of IPM are: that low pest levels should be tolerated; that pest containment rather than eradication is the key to management; that each problem has its own solutions; that a low level of damage or loss is tolerable;

that diverse control measures should be applied; that pesticides should be a last resort and the least disruptive should be used at the "lowest practical levels" (Fitt et al, 2004: 3).

The IPM system of the Australian cotton industry operates on the basis of four guiding concepts. These are the conservation and utilisation of beneficial species, the use of selective insecticides, the emphasis of both profit and sustainability and the integration of farm activities into a coordinated annual cycle (Fitt et al, 2004: 3).

Pest tolerant varieties are described by Fitt et al (2004: 3) as "the foundation" of IPM and, as such, GM insect resistant cottons "are a good platform for IPM". The cotton resistance management strategies that have been built on this platform "incorporate a broad range of biological and cultural tactics" (Fitt et al, 2004: 10). The coincidence of the "release of Bt cotton[19] and the industry wide extension effort on IPM" has led, through the success of this step, to the consolidation of grower confidence in the IPM concept (Fitt et al, 2004: 12).

Adoption of IPM has significantly changed grower attitudes and practices, promoting professionalism and an awareness of the need for scientific

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[19] Bt is the abbreviated form of *Bacillus thuringiensis*, a soil bacteria that is the source of certain insecticide resistance genes.

understanding and sustainability. These changes are reflected by quantifiable changes in the practices of growers, such as accurate record keeping and reductions in pesticide use on conventional cotton varieties (Fitt et al, 2004: 11).

The Australian cotton industry's Best Management Practice (BMP) program was initiated in 1993 as a strategy for improving "the industry's environmental performance" (Cotton Australia, 2000: 1). The idea was initially conceived and developed "against the background of a hostile community" (Macarthur Agribusiness, 2004: 52) and was finally introduced as an industry wide scheme in 1997 (Grabosky and Gant, 2000: 26).

Incorporating IPM, the purpose was a broader and more ambitious plan to "minimise the impact of cotton production on the environment" (Grabosky and Gant, 2000: 26). The intention was to institute best practice guidelines for IPM, farm management and farm design. A program of education that involved "practical manuals, best practice booklets, and training workshops for cotton farmers" was implemented and overseen by a BMP coordinator operating "at grass roots level" (Grabosky and Gant, 2000: 26).

An initiative entitled the Good Neighbours Program, a "vehicle to encourage all cotton growers to adopt BMP" was put into effect the following year (Grabosky and Gant, 2000: 26). It specifically set out to recruit growers to

BMP, to gain community recognition of the industry's commitment to improvement, to change entrenched negative perceptions, to challenge critics and to create a better "political environment" for the industry (Cotton Australia, 2000: 1).

Since then, "huge environmental and social advancements have been made" and pesticides, for example, are no longer regarded as a major problem, so new goals have been set (Macarthur Agribusiness, 2004: 52). BMP has become recognised as a marketing tool, as well as a means of achieving sustainability and improving community relations, so the advances of the past ten or fifteen years can be applied to sell the product as well as to stabilise the industry (Cotton Australia, 2005b).

The cotton industry has, therefore, investigated the concept of "badging" BMP cotton and a gap in the market has been identified for "better cotton, better grown, that cannot be claimed by our international competitors" (Cotton Australia, 2005b). It has accordingly developed objectives of "differentiating Australian cotton ... from that of our competitors", and providing an incentive for "growers, ginners, classers and marketers to support this ... industry initiative" (Cotton Australia, 2005b).

Genetically modified cotton

Given the availability of the technology, the forward-looking attitude of cotton growers and the pressure of the practical and political problems that it was facing, it seems in retrospect quite unsurprising that the cotton industry was so quick to develop and adopt GM technology. The incentives were strong:

> The increasing difficulty of controlling cotton bollworm, *Helicoverpa armigera*, in Australia due to its resistance to many chemical insecticides and the pressure to reduce the usage of chemicals led to the adoption of transgenic cotton as the key component of its pest control strategy by the Australian cotton industry. (Akhurst, James and Bird, 2006).

Ingard cotton was the first GM crop and "the second genetically modified organism (GMO) to be released into the Australian environment for commercial use" (O'Neil, 2007: 1). The essential features of this innovative development in crop protection were summarised by Agrifood Awareness Ltd:

> In 1996, insect-resistant GM cotton was grown commercially for the first time, after six years of field trials. Known as Bt or *Ingard* cotton, the GM cotton developed by CSIRO, using a gene owned by Monsanto, contains a gene from the soil bacteria *Bacillus thuringiensis* (Bt), which allows the plant to produce the Bt protein which kills cotton's major pest, heliothis or the cotton bollworm, when it eats the leaves. (AFAA, 2003: 1).

It might be added that the (Bt) protein in point (more specifically known as Cry1Ac) (Akhurst, James and Bird, 2006) is one of a number of identified Bt proteins that are specifically toxic to true caterpillars (Lepidoptera larvae) but harmless to other insects, fauna, humans and the wider environment.

The Bt genome is a rich source of genetic material with insecticide-generating properties. "Many thousands of different isolates of *B. thuringiensis* have been collected and their insecticidal protein content and activity spectrum determined". These have been classified according to a "naming system based on their protein sequence and the type of insects for which they are toxic" (Llewellyn et al, 1992). For example, genes classified under the "Cry 1" prefix are toxic to insects belonging to the order Lepidoptera (moths and butterflies) and "Cry 2" genes, are toxic to both Lepidoptera and Diptera (flies and mosquitoes).

But the activity of *Ingard* cotton had an even more specific focus. According to Constable, Llewellyn and Reid (1998) "the protein [Cry1Ac] is specific to sites on the gut wall of a few Lepidopterous species". This leads to an additional advantage in terms of specificity. Since the protein can only be ingested by consumption of plant tissue, the range of possible targets is reduced to those members of the order Lepidoptera that are both vulnerable to the protein and capable of parisitising cotton. Thus the new *Ingard* cotton variety, which had had the Cry1Ac gene inserted into its genome, was able to precisely target those insect species that belonged to a small group within a single insect order.

The adoption and performance of GM cotton in Australia

Monsanto's GM *Ingard* cotton was first sown commercially in the 1996-1997 growing season, when 30,000 ha, or 10% of the total cotton crop, were planted to the new variety. This area grew in regulated annual increments of up to 5% of the total crop area to the maximum that was allowed for *Ingard*, which was 30% of the total crop area, or 165,000 ha, in 2001-2002 (AFAA, 2004b; Constable, Llewellyn and Reid, 1998). This maximum was a product of the consciously cautious but flexible approach that was taken to managing the risks inherent in the GM crop. It recognised that: "management to prevent or delay the development of resistance to Bt in the target insect pests is … the key to the successful and long-term use of *Ingard*" (Constable, Llewellyn and Reid, 1998).

Risk assessment during the development phase and the early years of the commercial production of *Ingard* was coordinated by the non-statutory forerunner of the OGTR, the Genetic Modification Advisory Committee (GMAC) and approved "in the absence of other mechanisms" by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) (Radcliffe, 2006). The approach was science-based and, in terms of risk, conservative and meticulous. It involved the implementation of a detailed Resistance Management Strategy (RMS), sometimes referred to as a Resistance Management Plan (RMP) by Monsanto and the cotton industry as a condition of approval and use (AFAA, 2004b).

Beyond the more elementary questions of biosafety that are routinely dealt with during the earlier developmental phase of GM varieties, the probability of serious environmental risk was considered within the framework of three distinct areas. These were that *Helcoverpa* might develop resistance to Cry1Ac, that *Ingard* could outcross to native Australian cotton species and that populations of non-target insect species might be unintentionally harmed by Cry1Ac. The last of these was found to be of very low probability, but in the first two cases, higher probabilities demanded that a number of sometimes quite exacting, control measures be imposed (AFAA, 2004b). These requirements placed a significant burden of responsibility upon cottongrowers.

The practices and standards that growers of GM cotton are required to follow are demanding, but flexible and responsive in nature. They are reviewed seasonally in accordance with the prevailing conditions and the state of the science:

> Because Bt cotton involves the use of biotechnology, like other genetically modified organisms (GMOs), it is subject to stricter regulatory control than conventional varieties ... Of particular concern is the risk that insects will develop tolerance to Bt varieties. Every season the Transgenic and Insecticide Resistance Management Strategy (TIMS) committee of the Australian Cotton Growers Research Association (ACGRA) undertakes a detailed consultation with the cotton industry to develop the Insect Resistance Management Strategy (IRMS).

> Growers of transgenic cotton are required to sign an agreement (under the Agricultural and Veterinary Chemicals Act 1994) to follow an Insect Management Plan. (LWA, 2005: 86)

When *Ingard* was introduced, the measures included provision for: restrictions pertaining to geographical location, a cap on the overall portion of the cotton crop that could be planted to *Ingard*, the establishment by each grower of appropriate "pest refuge" crops, compliance with recommendations for planting and harvesting timetables, compliance with spray thresholds and "pupae busting" or post harvest cultivation requirements (AFAA, 2004b; LWA, 2005: 86).

The retention of these practices has remained central to the industry's approach to maintaining sustainable production of GM cotton. Growers of the current variety are "required to follow the *Bollgard II* Resistance Management Plans" (AFAA, 2004b). Under the terms of the OGTR licence, Monsanto is required to "ensure appropriate training for persons covered by the licence" (OGTR, 2002: 90) and it has accordingly "established stewardship protocols … including a training accreditation course that growers must complete and pass before they can buy the technology" (Perry, 2004).

The most restrictive of the measures originally taken was the cap on the percentage of the overall cotton crop that could be sown to *Ingard*. This was initially set at 10% and was finally pegged at 30% in 2001-2002, a constraint that reflected the vulnerability of the single Bt gene to the biological pressure for pest resistance to develop (AFAA, 2004b; Constable, Llewellyn and Reid, 1998). A late season decline in the Bt protein levels of *Ingard* cotton had been observed by researchers, and this decline was found to coincide with the survival of some *Helicoverpa* larvae, a combination of circumstances that was potentially conducive to the development of more strongly resistant genetic combinations. Consequently, the cap was pegged at 30% of the crop as "a resistance management precaution" (LWA, 2005: 87).

By this time, however, research was well advanced in the development of the more sophisticated *Bollgard II*, which has two different Bt genes and was first trialled in 1997-1998. The OGTR granted Monsanto a licence for *Bollgard II* in 2003 and it has since replaced *Ingard*, (AFAA, 2003: 1, 2; Constable, Llewellyn and Reid, 1998).

As a safeguard against the outcrossing of *Ingard* cotton to either native or feral cotton species, its terms of approval initially limited its use to specified shires located below the latitude of 22 degrees South. Cotton is killed by frost, but in frost free climates can survive as a perennial shrub. It was considered that at or below this latitude, frosts would reliably kill any plants or escapes that were not otherwise destroyed by the end of the growing season (AFAA, 2004b; Constable, Llewellyn and Reid, 1998).

Outcrossing was, anyway, not considered likely. CSIRO cotton breeders, Constable, Llewellyn and Reid reported to the Australian Agronomy Conference in Wagga Wagga in 1998 that "extensive studies" have shown that the likelihood of genetic crossover from cultivated cotton to endemic species is "negligible". They pointed out that any hybrids "that can be artificially produced are completely sterile", while in 200 years of Australian cotton cultivation "no natural hybrids with native species have ever been reported". However, they warned that the potential for weediness and outcrossing is "not a trivial issue", citing a case of the transferral of a herbicide resistance trait from canola to wild turnip (Constable, Llewellyn and Reid, 1998).

The 22 degrees latitude South restriction was eventually abolished on different scientific grounds. In a media release of the 26 October 2006, the Gene Technology Regulator, Dr Meek, explained the decision:

> Recent research has demonstrated that caterpillar pests are not the major factor controlling cotton growth in northern Australia. The spread of cotton is mainly limited by the availability of water and nutrients, and/or competition from other plants and insects such as grasshoppers. Therefore the genetic modifications will not make the GM cotton lines weedy. (OGTR, 2006b).

All cotton growers are required to provide specified areas of "pest refuge crops". Pest refuges may be large areas of sprayed conventional cotton, small areas of unsprayed conventional cotton, or other crops such as sorghum or maize in which the pests can thrive and breed (AFAA, 2004b; Constable, Llewellyn and Reid, 1998). The rationale behind this strategy is based upon elemenary principles of genetics. In conjunction with the other measures taken to minimise the population of pests that have been exposed to Bt cotton, the active propagation of much larger populations without this exposure means that the "resistance genes … will be diluted by mating with moths from the refuge" (Constable, Llewellyn and Reid, 1998).

Pupae destruction through post-harvest cultivation had (as indicated above) been an important element of conventional control of *Helicoverpa armigera,* with the purpose of minimising both early season pest numbers and any season to season carryover of genetically carried chemical resistance. The continuation of this practice was considered to be critical to the success of *Ingard*, as any influential level of carryover of resistance would result in it quickly becoming ineffective (Constable, Llewellyn and Reid, 1998).

Given the critical role of generational selection in the development of resistance, steps were also taken to limit the number of generations of *Helicoverpa* that could mature and reproduce within a crop each season. The "period of selection imposed on the insects" (Constable, Llewellyn and Reid, 1998) was constricted by controlling the length of the growing season. This was achieved at the industry level through a requirement that growers comply with "planting windows and plough-down dates" (Constable, Llewellyn and Reid, 1998).

Spray thresholds are specified levels of pest populations at which spraying is recommended. The population level within a particular crop can be established for the various stages (eggs, larvae, pupae, adult) of insect development, by counts within measured sample areas (Constable, Llewellyn and Reid, 1998). Compliance with spray thresholds ensures that control measures are implemented before insect numbers exceed readily manageable levels. This minimises economic loss through damage and contains the development of genetic resistance in pest populations in Bt crops.

Further requirements of the *Ingard* RMS obliged growers to follow procedures designed to prevent the occurrence of volunteers, to destroy any volunteers that might occur, to adhere to practices conducive to the preservation of beneficial predator insects and to avoid the use of Bt sprays on Bt crops, which would promote the selection of Bt resistant individuals (CCC CRC, 2006b).

The agronomic performance of *Ingard* and the effects of the circumspect provisions of the RMS appear to have met the most optimistic of industry expectations. Six years after its introduction, Dr Gary Fitt, a Director of CSIRO Entomology, described GM cotton technology as "the quantum leap forward for the industry" (AFAA, 2004b). The Grain Research and Development Corporation (GRDC) referred to the adoption and impact of

GM cotton in equally enthusiastic terms. "Genetically modified cotton was introduced in Australia in 1996 without a whisper of controversy and has transformed an ailing industry, beset by insect and disease problems, into a billion dollar-a-year export success story" (Perry, 2004, 1).

Although most growers reaped multiple economic and management advantages from having access to *Ingard* cotton, the most dramatic impact was undoubtedly the immediate and remarkable decrease in the frequency of applications of chemical insecticides. The adoption of *Ingard* led directly to a reduction by 50% -60% of sprays against caterpillar pests (AFAA, 2004b, 3; Peacock, 2003, 1; Roush, 2004, 2). Land & Water Australia is more specific (LWA, 2005: 85), recording, for *Helicoverpa* sprays, "an average annual reduction of 56% and a reduction of 80% in light insect years, for *Ingard* cotton, based on CRDC surveys".

With respect to the conspicuous success of the technology, the *Ingard* experience was central to the consolidation of grower acceptance of the more environmentally sensitive approaches to pest management that are inherent to IPM programs. The CSIRO's Dr Gary Fitt observed that *Ingard* "has allowed growers to become more confident with managing pests in softer ways" (AFAA, 2004b). Accordingly, use of the potent but environmentally undesirable chemical endosulfan has been reduced by 90% (AFAA, 2004b;

LWA, 2005: 85), with an ensuing "decline in endosulfan contamination levels in rivers in cotton producing areas" (LWA, 2005: 85).

In terms of quantitative reductions in chemical applications, total pesticide use in the Australian cotton industry was estimated by the former Cotton CRC (Cooperative Research Centre) to have declined by 6,200 tonnes of concentrates annually as a consequence of the combined strategies of IPM (Cotton Australia, 2006, 8). The central IPM measure overwhelmingly influencing this massive cut-back in pesticide use was the adoption of GM varieties, including *Bollgard II.* While the high figure for the overall tonnage decrease is informative, falls in the rates of chemical application, that have significance at the individual enterprise level, are of greater agronomic, economic and environmental importance. The introduction of *Ingard* reduced the average annual applied insecticide rate from over 6.0kg/ha to around 3.5 kg/ha (Roush, 2004, 4). Since the introduction of *Bollgard II,* it has fallen even more spectacularly to about 0.5 kg/ha, which results in a total decrease of about 5.5 kg/ha, or 92%, a reduction that was achieved over a period of less than 10 years.

The *Ingard* varieties were quickly phased out after the introduction of *Bollgard II* in the 2003–2004 growing season (CSIRO, 2003; LWA, 2005: 87; Perry, 2004: 1). Although *Ingard* had involved the use of only a single Bt gene and was thus potentially susceptible to the evolution of pest resistance to it, the practicality of the technology and effectiveness of the RMS was confirmed by the performance of the variety. When *Ingard* as withdrawn, "no observable resistance to the Bt toxin" had been "detected" (LWA, 2005: 87).

With regard to the identified risk of unintentional impacts on benign and predator insects populations, CSIRO cotton breeders reported that no evidence of problems was observed:

> Large ecological impact studies failed to find any significant effect on the several hundred insect species found in cotton fields, other than the expected reduction in the numbers of the very few insect species that exclusively predate on or parasitise *Helicoverpa*, since the number of caterpillars, their food source in the *Ingard* crop, was significantly reduced. (Constable, Llewellyn and Reid, 1998).

International experience with Bt protein in various crops confirms these findings. In his 2004 HV McKay Lecture, Richard Roush referred to the quite widely believed, but erroneous understanding that GM Bt crops pose a threat to members of the wider Lepidoptera community such the Monarch butterfly.

> Impacts on non-target species have been intensively investigated and published since 1994, but in spite of the publicity generated by a small laboratory study on Monarch butterflies (and the lack of publicity to several more extensive papers published in 2001 in the Proceedings of the US National Academy of Science 2001), the effects of Bt crops on non-target species are clearly and consistently much less than in conventional agriculture. (Roush, 2004: 2).

Since little if any scientific evidence has emerged to support the negative predictions and the criticisms of Bt cotton varieties made from outside the industry, internal confidence in the technology has grown. Probably the most contentious aspect of GM cotton for growers has arisen within the industry itself and concerns the "technology cost". This is the price of the licence to grow the varieties (LWA, 2005: 87) and is effectively a royalty that is paid to the owner(s) of the gene patent, who, in the case of the *Ingard* and *Bollgard* (and *Roundup Ready*) cotton varieties is the Monsanto corporation. According to a Land & Water Australia study of cotton, the GM technology cost is a "major issue in the Australian industry" (LWA, 2005: 87). The price of a licence has soared through a period that has presented serious difficulty for many growers, on account of the long drought and falling cotton prices. Licence costs were around \$170/ha in 2002-2003, \$192 in 2003-2004, \$250 in 2004-2005 and growers "had the expectation of the price reaching \$300/ha in 2005-2006" (LWA, 2005: 87). However, simple analysis of the economics of the crop does not support the case that the licence cost imposes an unreasonable burden on producers and it is certainly less expensive than the chemical control alternative[20].

[20] For the year 2006-2007, for example, average cotton yields were over 1,910 kg/ha (NFF, 2008), and the cotton export price averaged A\$1.69/kg (ABARE, 2007a:58), so the average gross return per hectare was \$3227.90. If the technology cost was as high as \$350.00 a gross residue of \$2,877.90/ha (or 89.2% of gross receipt) would have remained. While other costs, such as sales commission, industry contributions, harvesting, ginning, transport, fertiliser, irrigation, capital investment and routine operations would no doubt account for a good deal of this residue, these figures suggest that there is still room for handsome profits to be taken, even on moderate acreages.

The *Bollgard II* variety that superseded *Ingard* has fulfilled its promise of further and heavier reductions in chemical applications. It was released for commercial trials in the 2002-2003 season and became generally available to growers in the 2003-2004 season with a 40% cap on plantings. In 2004-2005 when *Ingard* was withdrawn from the market, the industry cap was raised to 95% of the crop. Subsequently GM maximum area restrictions were abolished as the provision of 10% pest refuges had been determined to be a sufficient resistance preventative (Apted, McDonald and Rodgers, 2005: 535; APVMA, 2003: 5; AFAA, 2004b; CSIRO, 2003; LWA, 2005: 87). In that year *Bollgard II* was sown by 95% of all growers and 71% of the total Australian cotton crop was planted to *Bollgard II* (LWA, 2005: 87).

The *Bollgard II* genome has had two *B. thuringiensis* genes, Cry 1Ac and Cry 2Ab inserted into it (Mahon et al, 2003). The possibility that problematic levels of resistance to the *Ingard* gene (Cry1 Ac) would eventually develop through the simplicity of its "single site" of activity had long been recognised and the precautions of the *Ingard* RMS, particularly the 30% cap were a response to this concern. According to leading CSIRO cotton breeders Constable, Llewellyn and Reid, the addition of the Cry 2Ab protein considerably enhances the ability of *Bollgard II* to avoid pest resistance:

> This protein has a different site of action [from Cry 1Ac] in the larvae gut wall, so any insect possessing resistance to one Bt protein will be killed by another (sic). Ecological models demonstrate that this approach could delay resistance by a factor of ten; eg if resistance were to occur in five years with a

> single gene, then resistance would not occur for 50 years with the two genes. (Constable, Llewellyn and Reid, 1998).

Although this variety may be grown in unlimited amounts, growers are "required to follow the *Bollgard II* Resistance Management Plan" (AFAA, 2004b). Investigation of the potential for identified cases of natural *Helocoverpa* resistance to Cry 2Ab to develop is the subject of ongoing CSIRO research that aims to ensure the continuing effectiveness of the resistance strategy (CSIRO, 2005b).

At the time of its introduction, *Bollgard II* was projected to reduce pesticide use by 70 - 90% and it was launched with the expectation that its technological "life expectancy" might exceed 25 years (AFAA, 2004b, 3; CSIRO, 2005, 1; Peacock, 2003, 1; Perry, 2004, 1; Roush, 2004, 4). Benefits of this magnitude have been more generally reported in overseas experiences of "two-gene" cotton[21].

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[21] In the USA, Bt cotton has allowed insecticide use to be reduced by 70 - 90%, while in the Hebei Province of China, where it was introduced in 1998, it has reduced insecticide applications by 80% and overall costs by 30% (Roush, 2004, 1-2). In China as a whole, Huang et al (2004, 1) reported a slightly lower, but comparable, 60% (35 kg/ha) reduction in pesticide use and an overall increase of 10% in yield.

Roush also reports a remarkable reduction in cases of human poisoning from insecticides in China. Since its 1998 introduction to China, Bt cotton has been credited with annually preventing at least 200 deaths as well as several thousand less serious cases of insecticide poisoning (Roush, 2004: 1-2). Reduced risk of contamination of field workers is also relevant in Australia, where supplementary manual weed control is not uncommon.

Precise quantification of the benefit in Australia is not easy, partly because the variations in pest pressure between different districts can be large. A comprehensive, industry wide survey conducted by the Institute for Rural Futures on behalf of Cotton Consultants Australia during the 2004-2005 growing season established that growers applied, on average, a *total* of 3.25 sprays to *Bollgard II*, compared to the 11.8 that were applied to conventional varieties[22]. Ninety percent of growers applied only *one* spray for *Helicoverpa* to their *Bollgard II* crop (Doyle et al, 2005: 3, 6), which, given the necessity to combat resistance with chemical sprays, suggests that the current technology is close to being as effective as it is likely to get.

Grower acceptance has been rapid and the CRDC reported in its *Annual Operating Plan 2006-07* that GM varieties accounted for "almost 90 percent of plantings in the 2005-06 season" (CRDC, 2006: 2). Monsanto, which has the lion's share of the GM cotton market, gives the figure of 89% for "total biotech" cotton hectares harvested in 2005/2006 (Monsanto, 2006b). In December 2006, with reference to the areas planted in that season (2006/2007), it reported 86% of the total was planted to *Bollgard II*, 64% to

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[22] The survey also quoted various grower reports of the advantages of using *Bollgard II*. These included "ease of management for smaller growers", its suitability for "sensitive areas such as along the river and highway to minimise spray drift" and, by "taking care" of the "bugs", its capacity to "allow the grower to concentrate on nutrition and water" (Doyle et al, 2005: 5).

the herbicide resistant *Roundup Ready*[23] and 11% to the new release *Roundup Ready Flex*[24] (Monsanto, 2006b). These figures refer only to

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[23] Herbicide resistance is the other major modification of the cotton plant that is in commercial use in Australia. This trait accounts for the great majority of the GM crop acreage worldwide (Evenson, 2003). Herbicide tolerance confers economic advantage to the grower through decreased chemical costs and weed control operations. It also provides benefits in terms of biosafety, comfort and worry to operators and others having direct contact with chemicals. Cotton varieties modified to be resistant to less expensive and less toxic herbicides such as glyphosate and glufosinate make simple "over the top" spraying of the entire crop area possible (AFAA, 2003b, 1-2; AFAA, 2004b, 3; Charles, 2002: E3.1; University of Sydney, 2004, 1).

Typically, the wider environment benefits from the use of non-residual herbicide resistant crops, with reductions in the volume, frequency and toxicity of chemical applications. The United States Department of agriculture reckoned that by 2003, US farmers were annually substituting 5.4 million lb (2.4 million kg) of glyphosate for 7.2 million lb (3.3 million kg) of the previously applied chemicals that were 3.4 to 16.8 times more toxic and twice as persistent in the environment (USDA, ERS, 2003).

Roundup Ready cotton, Monsanto's glyphosate resistant variety was released in 2000 and achieved almost 40% market penetration (by area) "within two years of its introduction" (Fitzgerald, 2004, 2), reaching 64% by 2006-2007 (Monsanto, 2006b). The economic advantage it offers is "one explanation for the extremely rapid uptake of the "Roundup Ready" technology in the Australian Cotton Industry" (Crossan and Kennedy, 2004: 7). These University of Sydney researchers cite a "yield benefit of $225 per hectare" for "low weed pressure scenarios", while other economic gains "gave a total economic benefit of $395 per hectare". The licence cost of Roundup Ready® cotton was $50/ha in 2004/2005 (BDA, 2004: 28). Charles (2002: E3.7) found considerable variation in the net economic advantage gained, ranging from $130 to $587 per hectare according to the system of management used.

Glyphosate is regarded as safe and is used as an everyday domestic and industrial herbicide. "Low soil mobility, together with relatively little persistence and human and aquatic toxicity render glyphosate as (sic) potentially one of the least environmentally hazardous herbicides to non-target organisms" (Crossan and Kennedy, 2004: 10). It is considered to involve "an extremely low risk of off-site contamination" (Fitzgerald, 2004, 2).

Monsanto's varieties, but include "stacked" varieties with dual (Bt and herbicide resistance) traits.

The main limitation of *Roundup Ready* cotton is that "older cotton is less tolerant" to glyphosate, which restricts applications to young plants with "up to four true leaves" (Charles, 2002: E3.1). This stage of growth "reflects a very real application restriction" and later applications risk severe "yield penalties" (Charles, 2002: E3.4). Poor weather conditions, wet ground, dry ground (weed stress), too large an area to cover quickly and mechanical breakdowns can lead to a failure to apply the spray in time. If the "over-the-top" window between emergence and the four leaf stage is missed, control directed sprays and/or shields must be used, which reduce effectiveness (Charles, 2002: E3.1-E3.4). This writer stresses the risks of weeds developing glyphosate tolerance under an over-simplified regime and emphasised the importance of maintaining an integrated approach to weed management (Charles, 2002: E3.6).

Bayer Crop Science has developed a parallel variety that is resistant to the herbicide glufosinate, which has some similar advantages to glyphosate. In 2005, the OGTR granted it a commercial licence for a "phased introduction over 3 years to commercial scale planting" beginning in August 2006 (OGTR, 2005).

[24] A more recently released variety that can tolerate glyphosate for the entire season.

Chapter 5.

THE CASE OF GENETICALLY MODIFIED CANOLA[1]

Canola is a genetic derivative of both oilseed and fodder rapes. Since its introduction to Australian crop rotations in the late 1960s, it has become an important contributor to the mainstream cropping economy and is now well established as a major Australian export commodity.

Canola seed is primarily a source of edible oil that has a very desirable analytical profile. "It is low in saturates, high in monounsaturates and contains a high level of oleic acid" (NCGA, 2007), a combination that is regarded by nutritionists as outstanding. It is mostly consumed as cooking oil and as a processed food constituent, being an important raw material for margarine. Canola is also a promising prospect as a renewable energy source, in the form of biodiesel. Canola meal, the marc that remains after the oil extraction process, is a useful source of protein for animal foods (OGTR, 2002b: 3).

Because the "fatty composition of the oil is genetically controlled" (Raymer, 2002), canola was bred from various strains of the traditional but essentially

[1] This case study is based on material gathered before Victoria and NSW lifted their bans on GM canola. In the absence of data arising from general industry experience with GM varieties, it necessarily treats the Australian GM canola case material as the product of precautionary regulation.

inedible crop known as rape[2] or rapeseed, using conventional plant breeding techniques, during the 1950s, the 1960s and the 1970s. The process was undertaken in Canada and involved a series of ambitious, imaginative and often innovative varietal engineering programs. Extensive local research in canola producing nations such as Australia, over the last forty years has also been vital to the success of what has become an international crop and industry.

The story of canola's evolution as a new broadacre crop is, at one level, the narrative of an entire industry's sustained focus, over half a century, on the principles and values of high quality science, in the pursuit of a more attractive product. The fruit of this focus and commitment is "a new, high value oil and protein crop that has gained tremendous acceptance worldwide" (Raymer, 2002) and which annually yields some 12 million tonnes of oil with the capacity to enhance public health everywhere (Downey, 2006: 67). It is also a story that, through its somewhat complex narrative threads, sets out much of the context from which the idea and the science of genetic modification sprang.

[2] The names "rape" and "rapeseed" are derived from the Latin word *rapum*, meaning "turnip" (DPI Victoria, 2000: 1) *Brassica rapa* is the botanical name for the turnip and the ancient line of rapeseed is in fact a variant of the common turnip with which it can freely breed. Linnaeus incorrectly classified them separately, as *B rapa-rapa* meaning "root" (the turnip) and *B. campestris* meaning "of the field" in the 18th century. The error was later recognised and rectified (Thomas, 2003: 1).

The Origin and History of Canola

The plant is a member of the Brasscicaceae family[3], which consists of some 375 genera and 3200 plant species mainly originating in the northern hemisphere (OGTR, 2002b: 2; Thomas, 2003: 1). The genus *Brassica*, to which canola belongs, is comprised of about 100 species, many of which are quite important food or fodder crops in Australia and elsewhere. It includes such familiar plants as cabbage, cauliflower, swede, broccoli, Brussels sprouts and mustard. (DPI Victoria, 2000: 1; OGTR, 2002b: 2). It also includes a number of important weeds[4] such as bird rape (*B. campestris* L.) and wild turnip (*B.tournefortii* Gouan.) (Lamp and Collet, 1984: 78-79).

Canola has been developed from three distinct varietal groups, which are derivative of several older oil crop species. The first two, *Brassica rapa*[5] and *Brassica napus* L., spp. *oleifera* are both commonly known as "oilseed rape"

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[3] The Brasscicaceae or "cabbage" family is still quite frequently referred to by its former family name of "Cruciferae", and its ubiquitous vegetable crop members are still commonly called "crucifers". This name arose from the characteristic formation of the four petals of the flower, which resemble a cross (Thomas, 2003: 1).

[4] Around 52 genera and 160 species belonging to Brasscicaceae are recorded in Australia (OGTR, 2002b: 2). A number of these species are of considerable economic importance as crops, but the family also includes "a host" of troublesome and often economically significant weeds of croplands, pasture and wasteland (Thomas, 2003: 2).

[5] *B. rapa* is an ancient species that is the oldest known form of rapeseed.

or "rapeseed"[6]. The third is *Brassica juncea*[7], otherwise known as "brown mustard". For historical reasons relating to the immediate origin of different germplasms[8], the Canadians, who provide much of the canola literature, often refer to *B. rapa* as "Polish canola" and *B. napus* as "Argentine canola". For similar reasons, *B. juncea* is sometimes called "canola quality brown mustard" (Thomas, 2003: 1).

Genetic evidence suggests that *B. napus*[9] with 19 chromosomes is very probably the product of a union between *B. rapa* (the turnip species, with 10

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[6] *B. napus* is believed to have arisen in either the Mediterranean or northern Europe in the middle ages, probably about a thousand years ago, but certainly before the 13th century when it was being grown in Europe (OGTR, 2002b: 2; Raymer, 2002; Thomas, 2003· 2). Since no wild form of the species has been identified, its genesis is considered most likely to have been the consequence of human activity Its origin was probably as a selection made from hybrids resulting from accidental crossings that occurred between older, cultivated *Brassica* species, (Raymer, 2002).

[7] *B juncea* is a recently introduced (2002) form of canola that was conventionally bred in Canada from brown mustard lines. Its advantages are that it is agronomically better suited to some soils and climates than the older varieties and the mature pods do not shatter as easily, which facilitates harvesting operations (Thomas, 2003: 3).

[8] Germplasm is the genetic resource or plant-breeding raw material.

[9] The traditional cattle and sheep fodder crop *B napus var. napus*, which is also rather confusingly referred to as "rape", is a closely related, but visually quite distinct variant that tends to produce abundant leafy material rather than bulbs or flowers and oily seeds (DPI Victoria, 2000. 1; Knox, Thompson and Campbell, 2006· 59). Its use is confined to the provision of stock fodder.

chromosomes) and *B oleracea* (the cabbage species, with 9 chromosomes) (OGTR, 2002b: 2; Thomas, 2003: 2).

Archaeological evidence suggests that the cultivation and use of *Brassica* species has been established for several thousand years, which places them "among the oldest cultivated plants known to humans" (Raymer, 2002). *B. rapa* is known to have been grown around 2000 BC in India, and there are indications that it was cultivated and used as early as 5000 BC (Colton and Potter, 1999: 1; Raymer, 2002; Thomas, 2003: 2). By 2000 years ago its distribution ranged from the north of Europe[10] to East Asia with a "primary centre of diversity in the Himalayan region" (Raymer, 2002).

Before the industrial revolution, the special value of rapeseed primarily lay in its qualities as a source of lighting oil (Colton and Potter, 1999: 1), for it could be grown almost anywhere and when oil was extracted and burned it "produced a smokeless, white flame" (Thomas, 2003: 2). It also seems to have been used to some extent for cooking, despite the presence of

[10] Rapeseed is tolerant of low temperatures, requiring relatively few heat units to successfully complete its reproductive cycle and since this characteristic is rare among oil-producing plants, rapeseed was of particular value as a readily cultivable oil source in northern Europe before trade and modern economies provided alternatives (Thomas, 2003: 2).

compounds with very strong and unpleasant flavours and often high levels of constituents that have since been determined to be toxic[11] (Thomas, 2003: 2).

The arrival of steam power with the Industrial Revolution led to a substantial increase in demand for rapeseed oil as it had the peculiar ability to "cling to water and steam washed metal surfaces better than any other lubricant" (Thomas, 2003: 2). It was this invaluable and unique quality that was to lead directly to the establishment of rapeseed production as an organised sector of primary industry and, by this mechanism, if indirectly, to the establishment of the canola industry.

The most important and fortuitous step in the evolution of the modern, global canola industry was probably the decision to establish a rapeseed industry in Canada in 1942 to supply steam engine lubricant for allied railways and shipping (Downey, 2006: 68; Thomas, 2003: 2). This arose from the...

> .. critical shortage of rapeseed oil that followed the World War II blockade of European and Asian sources in the early 1940s. The oil was urgently needed as a lubricant for the rapidly increasing number of marine engines in naval and merchant ships. (Thomas, 2003: 2).

[11] Keith Downey, a plant breeder who was a leading figure in the post-war canola development program, vigorously defends the post-war initiative to promote its consumption, asserting that "Asian peoples had consumed rapeseed oil for centuries with no ill effects" (Downey, 2006: 68).

Canada was able to provide the necessary resources and since it was an advanced western democracy, well removed from the theatres of war, the supply was likely to be reliable. Small pre-war research-station trials using seed of Polish origin had already shown that the crop could be successfully cultivated "in the cooler, moister regions of the Canadian prairies" (Downey, 2006: 68).

However, seed was in short supply and even after devoting the first season to seed increase, relatively little was available for planting in 1943. Fortunately, a search located an alternative supply in the US, where seed companies were able to makeup for the shortfall with a total of 19,000 kg of seed that had originally been sourced from Argentina. The Polish seed already propagated in Canada was a strain of the ancient *B. rapa* line, while the Argentine seed was of the derivative *B. napus* variety (Thomas, 2003: 2).

Although this phase of the industry's development was limited by the duration of the war and the continued use of steam technology, an organised and productive agricultural sector was born. Farmers had learnt that "rapeseed grew well on the prairies and was well suited to the climate of the parkland region" (University of Saskatchewan, 2007). They had also learnt that although *B. napus* "outyielded" *B. rapa*, it required a longer growing season and was more subject to shatter[12] of the seed pods at maturity

[12] Premature pod opening with loss of seed.

(Thomas, 2003: 2). In consequence *B. rapa* quickly became the preferred variety of growers.

Through the war years the Canadian Government had guaranteed farmers a price of 6 cents a pound to ensure supply and the sown area had grown to a respectable 79,000 acres (32,000 hectares) by 1948 when this guarantee was removed (Downey, 2006: 68). By this time diesel had become the preferred engine technology of western post-war industry and steam was in decline, so the market was collapsing and with no more price support, the outlook was not optimistic. Unsurprisingly, by 1950 the crop had all but disappeared from Canadian farms (Downey, 2006: 68).

At about this point in time, it became apparent that a market for edible rapeseed oil existed in Japan, where it was preferentially sought as a deep frying medium. The traditional Japanese practice of on-growing transplanted rapeseed seedlings in rice paddies through the interval between rice seasons had been abandoned in the post-war years because of a labour shortage, so rapeseed and frying oil were in short supply (Downey, 2006: 68).

This provided an unexpected opportunity for the Canadians to reap an immediate profit from their expertise and resources, with the possibility of gaining a foothold in a rapidly growing economy. More importantly, it provided the industry with the breathing space to develop a domestic market in Canada, which at that time was importing 90% of its edible oil needs (Downey, 2006: 68).

There were, however, obstacles to the sale of rapeseed oil as an edible product in Canada. The presence of very high levels of long chain fatty acids, (erucic acid particularly, and eicosenoic acid) was a peculiarity of the oil that had raised the concern of some nutritionists. Of the total fatty acids present in rapeseed oil (which represent almost all of its content), that extracted from *Brassica napus* was composed of 41% erucic acid and 15% eicosenoic acid, while the oil of *Brassica rapa* contained 23% erucic acid and 9.9% eicosenoic acid (Downey, 2006: 68).

Laboratory animal tests were undertaken to determine whether or not the consumption of rapeseed oil constituted a risk to health, but the outcomes were fairly unhelpful as results were inconclusive. While rats were "initially" reported to suffer from "enlarged adrenals" and reduced "performance" "under stress" there was no clear evidence of toxicity (Downey, 2006: 68). Some public controversy ensued, but the long record of apparently safe rapeseed oil consumption in Asia apparently won over the regulators, as well as sufficient consumers to secure a place for the product in the domestic market (Downey, 2006: 68). The area sown to rapeseed crops in Canada steadily increased from the low point of 1950 (Downey, 2006: 68, 75).

Although toxicity had not been demonstrated, non-specific concern with the safety of rapeseed oil consumption and, more worryingly, the unanswered questions about the potential dangers of long chain fatty acids constrained the ability of the industry to thrive and expand. As long as this uncertainty existed, the established market would remain vulnerable and the development of new markets would be very difficult. The "potentially very large" US market was already "closed ... because rapeseed oil had never been in widespread use there and was not included in the US "GRAS" list of foods (generally recognised as safe)" (Downey, 2006: 69). It became clear to the Canadians that the industry would not grow while doubts and allegations about the safety of rapeseed oil consumption persisted[13].

[13] Some fifty years later, erucic acid, which is present at trace levels in various oils, is still a controversial substance and is regarded by some authorities as a potentially dangerous biochemical agent. According to the UK Food Standards Agency, it has been "shown to cause fatty deposits in the hearts of test animals" when consumed at high levels (Food Standards Agency UK, 2004) Although these deposits remain only as long as erucic acid continues to be consumed and no unequivocal empirical evidence has been presented to show that it is a positive threat to good health in humans, their correlation means that a potential link to heart disease cannot be ruled out. A limit of "5% of the total fatty acid" is applied to erucic acid in foods in the UK. (Food Standards Agency UK, 2004).

Food Standards Australia New Zealand reports a link between the consumption of erucic acid and "myocardial lipidosis in a number of species ... [and] an association between dietary erucic acid and heart lesions in rats" (FSANZ, 2003: 4) but rules out an association between these conditions and "the consumption of rapeseed oil" in humans (FSANZ, 2003: 18). On the basis of animal studies, a "tolerable level for human exposure" is considered to be about 500 mg of erucic acid per day for an adult of average weight (FSANZ, 2003: 19).

The uncertainty about erucic acid in rapeseed was the genesis of a scientific response that ultimately led to the emergence of new crop: "chemists and breeders turned their attention to developing techniques to search for and develop germplasm with little or no long chain fatty acids" (Downey, 2006: 69). More specifically, this meant finding a means of "genetically blocking the biosynthetic pathway for fatty acid carbon-chain elongation, from oleic to eicosenoic to erucic, as the oil is laid down in the developing seed" (Downey, 2006: 69).

The enormity of such an undertaking by conventional plant breeding methods is may not be apparent outside the scientific circles concerned with this work, but the research was groundbreaking and its ultimate success is recognised as a scientific milestone:

> One of the most remarkable achievements of modern plant breeding was the development of canola quality *Brassica napus* from rapeseed by the reduction

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Current normal levels of consumption of canola oil are considered to pose no risk to "public health and safety" (FSANZ, 2003: 21).

The Australian Office of the Gene Technology Regulator (which has no direct responsibility in regard to the determination of toxicity) takes a different view and is less delicate about articulating the risks it perceives to be associated with rapeseed oil and its constituents. In the introduction to its background publication "The Biology and Ecology of Canola (*Brassica napus*)", it declares that - "Traditionally, *B napus* is unsuitable as a source of food for either humans or animals due to the presence of two naturally occurring toxicants, erucic acid and glucosinolates" (OGTR, 2002b: 2).

> of erucic acid content in the oil and glucosinolates in the meal. (Quijada et al, 2004: 1982).

Veteran Canadian canola breeder Keith Downey describes the development of canola as "a story of successful genetic manipulation of an introduced crop by a small, self-motivated team of chemists, plant breeders and animal nutritionists" (Downey, 2006: 67) and emphasises the technical difficulties associated with canola research conducted during the 1950s. As an example, he points out that "it required 2 lb of seed and a technician 1 week just to determine the fatty acid chain lengths of an oil" (Downey, 2006: 69)[14].

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[14] The Canola Council of Canada's *Canola Growers Manual*, outlines the complexity and the tedious length of the task of developing new canola varieties:

> "Variety development is a team effort that involves plant breeders, pathologists, crop quality chemists, physiologists and agronomists – as well as highly trained technicians to back up these professionals The plant breeders make crosses among promising materials and select for yield and quality characteristics. After several years of selection, promising lines are entered into private and public evaluation trials called Co-operative Tests that are located at over 20 locations across western Canada. After one year of testing in private trials plus one to two years in the public Co-operative Tests, the lines that meet all the required standards for oil quality, yield, herbicide tolerance and disease resistance are evaluated by the Western Canada Canola/Rapeseed Recommending Committee. Lines that meet the criteria of the Committee are recommended to the Canadian Food Inspection Agency for registration.
>
> It usually requires eight to 10 years from the initial crosses until a variety is registered, followed by an additional two to three years of seed multiplication before a variety is ready for commercial production". (Thomas, 2003: 3).

The first "low-erucic *B. napus* variety, "Oro" emerged in 1968 and was the product of a program centred on a "poorly adapted European forage variety with a much reduced level of erucic acid" (Downey, 2006: 69). Shortly afterwards, in 1971, "Span" the first "low erucic *B. rapa* variety" became available (Downey, 2006: 69).

Fortuitously for rapeseed producers, the major work on these "low-erucic" lines was completed just in time to save the industry from a potentially disastrous situation that arose just before "Span" was released. In late 1970, the Second International Rapeseed Congress, held in Canada heard that Canadian and European researchers had observed "abnormal numbers of heart lesions in laboratory animals fed high levels of rapeseed oil" (Downey, 2006: 69). The conventional product was now clearly a poor prospect for growers and oil producers and had this finding come a little earlier, it might have destroyed the industry overnight[15].

[15] A huge and immediate cooperative response from the "entire industry" enabled it to quickly adopt the new varieties and successfully overcome the problem (Downey, 2006: 69). The little existing low-erucic seed of both species was taken to California for "winter increase" and the seed thus produced sown again in Canada the following spring. In this fashion, the supply of low-erucic seed was rapidly increased to the point of meeting the industry's need for planting material. By 1973, the entire industry had successfully been converted to the new varieties and its "4 million acre crop" had been preserved (Downey, 2006: 69).

At this time, industry researchers were also investigating another concern about the chemical composition of rapeseed. This was the presence of high levels of glucosinolates in the mature seed, which particularly affected the high protein meal used for stockfeed that remained after the seeds were pressed to extract the oil.

The glucosinolates "are a class of about 100 naturally occurring thioglucosides that are characteristic of the Cruciferae and related families in the order Capparales" (NTNU[16], 2007: 1). They "are important aroma and flavour compounds in *Brassica* vegetables such as cabbage, Brussels sprouts, broccoli, cauliflower and horseradish" (Hansen et al, 1995: 1069). During the process of being broken down by enzymatic hydrolysis, glucosinolates release chemical products that are responsible for many of the plants' characteristic odours and flavours, including the "biting taste" of mustard and horseradish (NTNU, 2007: 1).

While glucosinolates occur in "all parts of the plant" (NTNU, 2007: 1) they are accumulated and concentrated "in the seed" (Downey, 2006: 72). They may constitute "up to ten percent of the dry weight" of seed, but in other parts of the plant account for only about a tenth of this level (that is around 1% of dry weight). An individual plant may contain as many as 15 distinct glucosinolates (NTNU, 2007: 1).

[16] Norwegian University of Science and technology.

Some glucosinolates have breakdown products, such as nitriles, thiocyanates, isothiocyanates (or ITCs, which are significant in biofumigation*), epithionitriles and vinyl oxazolidinethiones, all of which can have "toxicological effects" (NTNU, 2007). Consequently, the presence of these glucosinolates in agricultural crops such as rapeseed and *Brassica* vegetables is considered undesirable. Although, in part, providing plants with a mechanism protective against herbivores, parasites and a range of pathogens, the wider "biological role of glucosinolates and their degradation products" is an area of *Brassica* biochemistry and botany that is not well understood[17] (NTNU, 2007: 1).

* Explained below.

[17] The biochemical/botanical function of glucosinolates is closely associated with the activity of enzymes known as myrosynases, which occur within the same plants and catalyse the degradation of glucosinolates when the two associate. The products of the resultant hydrolysis appear to perform "important roles in the plant defence system against insect, fungi and microorganism infections" (NTNU, 2007: 1). While the evolutionary functions of the system appear to be "diverse", its complete purpose is not clear, although "the complexity of the myrosynase-glucosinate system indicates an important role in the life cycle of plants" (NTNU, 2007:1).

The hydrolysis of glucosinolates and the generation of the active breakdown products that are released is achieved as the result an unusual mechanical arrangement within the plant (NTNU, 2007: 1). Glucosinolates are understood to be located in the vacuoles of ordinary plant cells, while myrosynases are isolated from them in specialised "myrosin" cells. When tissue is damaged, such as by insect or microbial activity, the "two components of the system [are brought] into contact" and the breakdown products released (NTNU, 2007: 1).

The presence of glucosinolates at moderate levels is considered to provide positive nutritional and gustatory qualities to *Brassica* vegetables[18]. However, since their concentration is far higher in the seeds of most *Brassica* species, including those comprising traditional rapeseed crops, there is a clear potential for difficulties to emerge in seed crops grown primarily for consumption, especially if substantive quantities might be ingested. "Glucosinolate levels are not significant with respect to oil quality but do affect the quality of meal for livestock feed following oil extraction" (Livinstone et al, 1995: 1). Toxicity and excessive pungency are the obvious, potentially problematic characteristics of glucosinolates and these were the specific hurdles that the infant rapeseed oil industry had to overcome (Downey, 2006: 72; Thomas, 2003: 4).

Although rapeseed meal "is an excellent source of protein with a favourable balance of amino acids ... the use of rapeseed meal in rations was limited by its glucosinolate content" which "resulted in reduced feed efficacy" (Thomas, 2003: 4). The failure of stock to thrive was linked to the presence of high levels of glucosinolates in the meal. Although comparable to soy meal as a

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[18] In addition to the function in their natural location as instruments of plant survival, some glucosinolates, particularly (as is quite well known) those found in broccoli, have been identified as exhibiting anticarcinogenic activity (NTNU, 2007. 1). This characteristic of

source of protein and thus a potentially valuable dietary staple for non-ruminants, "feed efficiency and weight gains with swine and poultry were well below expected levels" (Downey, 2006: 71). A further, compounding difficulty was that palatability was low so animals were reluctant to eat it (Downey, 2006: 72).

These characteristics amounted to "a major market constraint" because they "restricted the amount of meal that could be fed and, in turn, limited the amount of seed that could be processed (Downey, 2006: 71).

When the cells of rapeseed are ruptured in the presence of moisture, among the products that are released through the hydrolysis of glucosinolates, are ITCs (isothiocyanates). Aside from a range of other properties, these compounds are "active goitrogens that interfere with iodine uptake by the thyroid gland in swine and poultry, resulting in goitre and poor growth" (Downey, 2006: 72).

Heat treatment of the meal itself, aimed at denaturing the enzyme involved, was the first approach that was investigated, but as it proved to be only a partial solution as hydrolysis was also found to occur "in the gut" (Downey, 2006: 72). Consequently, achievement of "the ultimate objective" - the

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these compounds is under investigation by various research institutions for its therapeutic potential (NTNU, 2007: 1).

suppression of glucosinolates at a genetic level - became imperative (Downey, 2006: 72, 73).

In 1967, the seeds of a Polish variety known as “Bronowski” were found to be a source of low glucosinolate genetic material (Thomas, 2003: 4). This material was incorporated into the low erucic acid breeding program and led to the development of the first low ereucic/low glucosinolate *B. napus* variety “Tower” in 1974 (Downey, 2006: 73; Thomas, 2003: 4). Low ereucic/low glucosinolate varieties have become known as “double low” varieties (Thomas, 2003: 4).

In 1977 a “double low” *B. rapa* rapeseed variety, “Candle” was also released “so that the second complete crop changeover could occur” (Downey, 2006: 73). Complete conversion of the industry to the “double low” varieties was largely achieved by 1980 and “extensive studies” by animal nutritionists have since shown that meal derived from these new varieties is “a safe, wholesome and economic high protein supplement” (Downey, 2006: 73).

By the early 1980s, the breeding programs of the previous thirty years had altered the old rapeseed varieties beyond recognition. A little valued, essentially redundant industrial crop had been genetically transformed, a small revolution in its end use had occurred and its economic value had been multiplied astonishingly. In short, a new crop and a new industry had been invented and established. Given the critical implications of these changes for the marketability of the final product, and the unfortunate accidental association of the word "rape" with rapeseed, a new varietal brand name for the new crop and product seemed a logical progression (Thomas, 2003: 4).

The new name that was coined, "canola", distinguished the new, edible-oil producing varieties from conventional rapeseed and was originally used as an industry trademark that was registered by the Western Canadian Oilseed Crushers' Association in 1978 (Canadian Canola Association, c2006: 20; Downey, 2006: 74; Raymer, 2002; Thomas, 2003: 4). The name was an acronym taken from the breeding history of the variety: "Improved varieties were named "canola" after the "**CAN**adian-**O**il-**L**ow-**A**cid" breeding program" (Livingstone et al, 1995: 1). However, it was quite quickly elevated from a brand name to a generic term. The success of canola has been remarkable and many billions of dollars worth of its product are now annually traded on the international market, so "the term "canola" is not just a Canadian term and is no longer an industry trademark" (Thomas, 2003: 4).

Canola seeds now "commonly contain 40% or more oil and produce meals with 35% to 40% protein" (Raymer, 2002). Its oil now typically contains less than 0.5% erucic acid, 5% to 8% saturated fats, 60% to 65% monosaturated fats, 30% to 35% polyunsaturated fats and less than 20 mmoles of glucosinolates per gram[19]. It has been widely promoted as a "health" oil (Colton and Potter, 1999: 1; Raymer, 2002).

Canola was given "Generally Recognised As Safe" (GRAS) approval by the US Food and Drug Administration in 1985, which led to the opening of markets there as well as in a number of other countries that are guided by US rulings and standards (Canola Council of Canada, c2006: 21; Downey, 2006: 69). A strong domestic industry, concentrated mostly in North Dakota, has since been established in the US and it is now the world's seventh largest canola producer, but the US continues to be a significant export destination for Canadian canola (AAFC, 2004).

In 1999 Codex Alimentarius confirmed the name "canola" as the accepted term for low erucic acid rapeseed and formally accepted the much more

[19] The word "canola" is defined in various acts of the Canadian Parliament (Thomas, 2003: 4) and "refers to cultivars of oilseed rape that produce seed oils with less than 2% erucic acid … and meals with less than 30 mmols (micromoles) of aliphatic glucisinolates per gram" (Raymer, 2002). Downey (2006: 74) reports a proposal to reduce these limits to 1% erucic acid and 18 mmols "of all glucosinolates in the whole seed".

recently developed *Brassica juncea* (canola quality mustard) as a form of canola (Canola Council of Canada, c2006: 5)[20].

Canola in Australia

Rapeseed (of Canadian origin) was first commercially cultivated in Australia in 1969 after trials conducted from the early 1960s. Interest in the crop was triggered by the imposition of quotas on wheat production (Colton and Potter, 1999: 1). The cultivars grown were very high in erucic acid and glucosinoles and although better quality strains were soon available, they were unpopular with Australian farmers as their yields were low. The emergence of a crippling susceptibility to "blackleg" disease in Australia emphasised the need for local breeding programs and these were initiated by Victoria, Western Australia and NSW, in that order, between 1970 and 1973. The desired combination of high quality, high yields and blackleg resistance, however, was not achieved until 1987 (Colton and Potter, 1999: 2).

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[20] Industrial grade rapeseed is still grown for non-food purposes and produces oils with 45% or more erucic acid and variable, but frequently high glucisinolate levels (Colton and Potter, 1999: 1; Raymer, 2002).

> "Specific uses of rapeseed and crambe oils are based on their long chain molecules or molecules with double bonds. Oils high in erucic acid have special attributes that make them useful in manufacturing. These include high smoke and flash points, oiliness and stability at high temperatures, ability to remain fluid at low temperatures and durability". (Erickson and Bassin, 1990: 24)

A wide range of applications exists for conventional rapeseed oil. In general, rapeseed yields at least 40% oil and 35% to 40% protein (Raymer, 2002).

Canola is commonly grown and is an easily identified crop when in flower, providing eye-catching expanses of vivid yellow colour through the cropping districts in spring. Varieties are of either a "spring" or "winter" type, a characteristic that is not related to species. *B. napus* and *B. rapa* occur in both spring and winter forms (Thomas, 2003: 7).

"Winter" types, such as are usually grown in Europe have a vernalisation (or chill factor) requirement and will not flower or yield satisfactorily without exposure to at least threshold levels of chill, measured as a product of magnitude and time. "winter" form of canola plant must be subjected to certain points and durations of low temperature in order to. These varieties are sown and established prior to the onset of winter and harvested the following autumn, 12 months after sowing (OGTR, 2002b: 3). Some winter type varieties of *B. napus* produce abundant quantities of high quality fodder and are commonly grown in Australia as a winter/spring grazing crop (Kirkegaard et al, 2006).

Spring types of canola, such as are grown in Australia, have no vernalisation requirement and are sown with the autumn break in April or May. These varieties flower for about a six week period and mature in late spring to early summer, 5 to 7 months after sowing (OGTR, 2002b: 3). Canadian canola varieties, which are also mostly spring types, are grown in warm conditions with long day lengths and are able to mature in less than 4 months (OGTR, 2002b: 3).

Both *B. napus* and *B. rapa* are grown in Canada, *B. rapa* being "better adapted to short season growing areas" (Thomas, 2003: 3).

> *B rapa* is an important commercial oilseed crop for Canada, Sweden, Finland China and India. It provides an alternative crop for areas subject to short growing seasons. *B rapa* differs from *B napus* in being a self-incompatible, obligatory outcrossing species. It is not currently produced as a commercial crop in Australia and is identified as a weed species. (GMAC, 1997: 1).

Because the rapeseed varieties introduced to Australia before the 1970s had been selected for Canadian and European conditions, they were unsuitable and the industry did not thrive until local breeding programs had successfully identified appropriate varieties (Cowling, 2006).

> When rapeseed was first grown commercially in Australia using imported varieties, blackleg (*Leptosphaeria maculans*) destroyed the industry. Overseas germplasm proved to have insufficient blackleg resistance for Australian conditions. As a result of intensive breeding and selection, most current Australian bred varieties are highly resistant to blackleg .. Overseas spring canola does not have sufficient resistance, meaning that new traits such as herbicide resistance must be incorporated into an Australian canola background before commercialisation. (Marcroft et al, 1999).

In Australia, canola seed is sown with the aim of establishing an optimum plant population level of 50-70 plants per square metre (this equates to sowing rates of 4 to 6 kg/ha, or 3 kg/ha for hybrid seed). Sowing depth is increased in warm, dry conditions (OGTR, 2002b: 3).

Assuming competent management, water availability, especially during the period of seed growth, is the most critical limiting factor to canola yield. The highest yields are achieved in a long cool season with an uninterrupted and adequate supply of moisture. Under average Australian conditions, yields are typically in the 1-2 tonnes/hectare range, but may reach 5 tonnes/hectare in exceptional circumstances (OGTR, 2002b: 3).

Biofumigation

Field experiments have confirmed that there is a scientific basis to grower observations that the addition of canola to traditional crop rotations led to greater vigour in following wheat crops (Kirkegaard et al, 1999). This effect is the result of canola's anti-pathogenic activity, which is known as biofumigation. It refers to:

> the suppression of soil-borne pests and pathogens by biocidal compounds, principally isothiocyanates (ITCs) released from Brassicaceous rotation and green manure crops when glucosinolates (GSLs) in their tissues are hydrolised. ... In broad acre cropping, *Brassica* oilseeds such as canola are thought to be superior break-crops for subsequent cereal crops, partly due to their biofumigation effects on cereal pathogens. (Kirkegaard et al, 1999).

More controllable "pot studies" and *in vitro* tests have revealed in more detail the extent and the mechanisms of the biofumigant capability of canola, particularly in respect of the "suppression of a range of soil borne cereal pathogens" (Kirkegaard et al, 1999).

Similar research with mustard has shown that glucosinolate hydrolysis products are capable of "suppressing weed seeds and pathogens" (Hancock, 2005: 7). An ongoing US research program into ITCs is directed towards refining and managing these products for use as sterilants in organic farming systems and even as a mainstream alternative to methyl bromide (Hancock, 2005: 7). Hancock, a Grain Development Officer in the Western Australian Department of Agriculture, writes that Indian mustard meal has been imported to Queensland at a cost of AU$300/t "for use as a biofumigant in high value horticultural enterprises and turf farms" (Hancock, 2005: 7. He reports that it has also been used as a "pet friendly" "active ingredient in snail pellets" (Hancock, 2005: 7).

The biofumigant activity of canola is generally considered by farmers to "unlock wheat yield" ("The Grower", Issue 15, May 2006: 2) and partly accounts for the rapid expansion of the Australian canola industry during the 1990s. The benefit, however, is not universal and has been observed to vary according to the pathogen status of a soil and other specific conditions that may apply to a location or affect a growing season. A soil with good pathogen status will probably show less wheat yield response to including canola in the rotation than to using a nitrogen-fixing legume crop such as lupins, beans or peas (Rice, 2005).

A review of crop rotation alternatives by agricultural consultants in central NSW shows that the inclusion of canola in cereal crop rotations may increase the yield of subsequent wheat crops by as much as 72%, and on average, does so by 19%. The yield benefit resulting from the effects of canola may persist into the second and third wheat crop that follow it, with average yield benefits over that time of up to 13% (Rice, 2005)[21].

Canola is by no means a panacea for cereal disease control, but its adoption into rotations has been "particularly effective" in combating the fungal disease "take-all", "the major root disease in southern NSW" (Murray, 2004). It has also been found to control a range of root diseases in other crops such as cotton, beans, sesame and carrots. The modes of action of glucosinolates seem to be quite complex and in addition to direct anti- pathogenic activity, they appear to stimulate the growth of beneficial microbes that themselves have anti-pathogenic functions (Smith, 2001: 1).

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[21] General acceptance of the value of canola in crop rotations is evident at both administrative and grower levels. In 2000 the Victorian DPI described canola as "an excellent choice to enhance or extend a crop rotation. It is a high yield and profitable crop in its own right as well as an excellent fit with cereals or pulses" (DPI, 2000: 2). It suggested that a realistic target yield was 2.0 to 2.5 tonnes per hectare and that a 2.0 tonne crop would "return a gross margin of $400 per hectare compared to $230 per hectare for a 2.5 tonne per hectare wheat crop" (DPI, 2000: 2). In 2006, a successful northern Victorian grower (DPI, 2000: 2) reported yields of 2.4 tonnes per hectare and a gross margin of $500 per hectare for both canola and cereals. This grower considered that canola and cereal crops were mutually beneficial, asserting that "canola is necessary in the rotation to grow a good cereal crop, and cereal is essential to growing a good canola crop" (Pritchard, 2006: 2).

Canola Production

Among vegetable oils produced worldwide, canola is ranked second to soybeans, and by 2000/2001 accounted for 13% of total oilseed production (Raymer, 2002). It has progressively outstripped peanut, sunflower and cottonseed since significant production began in the early 1980s with a peak of 47.4 million tonnes in 1998/1999. A low point of 32.5 million tonnes occurred in the poor 2002/2003 season and production has since risen again to 42.3 million tonnes in 2004/2005 (Oilseeds WA, 2005: 2; Raymer, 2002). In 2004/2005, the EU, the world's largest producer was responsible for the production of 14.3 million tonnes of canola, 34% of the world total, with China, Canada and India producing 12.0, 7.0 and 5.8 million tonnes respectively (Oilseeds WA, 2005:2).

After a period of very consistent increases in canola production and consumption over the last two decades, the current market trend suggests that a market plateau and possibly even a ceiling has been reached (Oilseeds WA, 2005:3). World production has not returned to the 1998/1999 level and five key producer nations seem to have emerged, whose share of the market has consolidated at the expense of smaller producer nations that have apparently abandoned the crop (Oilseeds WA, 2005: 3). Australia is the fifth, or smallest, of these key producers and with a yield of 1.5 million tonnes produced 3.5% of the world's canola in 2004/2005.

However, as an export-focussed industry its share of the global market is proportionally greater than the bare production figures might suggest and it is the world's third largest canola exporter, after the EU and Canada (Smith and Jimmerson, 2005). In 2002/2003 (a drought year in eastern Australia) Australia grew only 1.5% of the world crop, but its exports still amounted to 7% of total international canola trade (Smith and Jimmerson, 2005; Oilseeds WA, 2005: 3).

Production in Australia is undertaken mostly in NSW, Victoria, SA and WA. Areas sown and total state yields are quite variable, although WA tends, on average, to be the largest producer. Victoria's production volume has been more consistent than the other States since the turn of the century, probably due to more stable rainfall patterns (Oilseeds WA, 2005: 2).

Table 5.1

	VIC	NSW	SA	WA	TOTAL
TONNES	358,000	300,000	232,000	399,000	1,289,000

Average canola production by state, 2000 to 2005. Source: Oilseeds WA, 2005

Canola is Australia's major oilseed crop. It is the source of 57% of the nation's oilseed, while a further 36% is derived from cotton (AOF, 2005), so the two industries typically provide over 90% of Australian oilseed. ABS placed the gross value of the 2003/2004 Australian canola crop at A$685.7 million, up from the previous (drought) year's value of A$388.8 million. In 2001/2002 the value was a comparable A$675.0 million (ABS, 2005: 13).

Australia's canola industry does not compare in size with wheat or cotton, but it is a significant and substantial crop that is important to the economic health of rural Australia. In 2003/2004, total agricultural commodities had a national value of A$36.9b of which the State of Tasmania's share was A$857.0m (ABS, 2005: 4&6). In that year, at A$685.7 million, canola accounted for 1.9% of gross Australian agricultural returns, which was equivalent to 80% of total Tasmanian agricultural production. Compared to the performance of other sectors, this was almost one and a half times the value of Australian potato production and more than double the value of Australian egg production (ABS, 2005: 11&16).

Herbicide Tolerant Canola

Although herbicide tolerance has become publicly associated with GM technology, especially in the case of canola, conventional plant breeding programs have explored this area of the science for some time:

> Canola has natural tolerance to a range of herbicides such as the grass selectives, trifluralin and clopyralid. Tolerance to other herbicides has been achieved by intensive, conventional selective breeding and by gene transfer technology. (Madin and Bowran, 1999: 1).

Two herbicide-tolerant canola types of economic significance are grown in Australia. These are selections that have genetic tolerance to either triazines

("TT" canola) or imidazolinone ("IT" canola). Both of these lines of the plant were bred by methods that are classed as "conventional"[22].

Imidazolinone resistant canola varieties have been in commercial use in Australia since 2000 and have been planted to a moderately significant extent, despite some drawbacks. No compromise of yield or oil quality in comparison to conventional canolas has been associated with the cultivation of imidazolinone resistant varieties. However, the particular herbicide group involved (Group B) is described by the OGTR's *Biology and ecology of canola (Brassica napus)* as "high risk in terms of development of herbicide resistance [by weeds]" (OGTR, 2002b: 24). According to OGTR, "resistance has emerged in some areas of Western Australia so that the use of IT canola varieties is limited".

Madin and Bowran, in literature published by the Western Australian Department of Agriculture, specify four other areas of weakness. They report that in their experience, the Imidazolinone imazethapyr is

> a relatively expensive herbicide and although with (sic) a good weed spectrum, it is slow acting and offers suppression rather than control of some weeds. It

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[22] The term "conventional" is used to distinguish older methods of plant breeding from GM and its associated techniques. The practices involved, however, are not confined to simple or essentially "natural" procedures such as selective cross-breeding, but may include mutagenesis, a process of induced mutation involving stimulation from either chemicals or radiation. Unlike GM, which is precise, it produces new genetic patterns and combinations at random from which individuals may be selected for further research and propagation.

> has also demonstrated residual activity on following cereal crops on occasions. (Madin and Bowran, 1999. 1).

Weed researchers, Peterson et al (2001: 11) of Kansas State University have reported the incidence of acquired weed resistance to acetolactate synthase (or ALS) inhibitors (the group of herbicides to which the imidazolinones belong) in a number of weeds. With respect to other pertinent characteristics they comment:

> These herbicides have exceptionally low mammalian toxicity and have minimal environmental concerns because of low use rates. Herbicide drift and spray contamination, however, are a concern because susceptible crops are very sensitive to these chemicals. Many of the ALS inhibiting herbicides can carry over in the soil and injure subsequent crops. (Peterson et al, 2001: 11).

While certainly not environmentally catastrophic, the negative aspects of the imidazolinones, especially their persistence and the rapid development of resistance, would appear to rule imidazolinone tolerant canola out as a long-term prospect for Australian farmers[23].

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[23] An agronomic "package deal" consisting of a patent herbicide (containing imazapic and imazapyr) as well as "imidazolinone tolerant canola seed and a Best Management Practice Program" (Jackson and Paton, 2000) has been marketed under the "Clearfield Production System" brand name in Australia since 2000 by the German-based chemical company, BASF. "Clearfield" seed is the product of a breeding program involving gene patterns constructed by chemical mutagenesis, a process of deliberate stimulation of gene mutation that is classed as a conventional plant breeding practice (Biotechnology Australia, c2007). This package has also been successful in Canada, where no triazine tolerant canola is grown, and currently accounts for about 20% of total Canadian canola acreage. GM varieties account for about 70% of the total area of Canadian canola and conventional varieties make up the balance of around 10% (Crabtree, 2006: 2).

Triazine tolerant canola first became available in Australia in 1993[24]. The use of chemicals from this group of cheap "pre emergent" weedicides allows an entire crop to be sprayed, either at or shortly after seeding, with a triazine herbicide (simizine and atrazine are applied to canola in Australia) capable of killing weeds in the early stages of root development (Colton and Potter, 1999: 2; Davies, Cook and Barton, 1994: 209; Piper, 1996; Stanley, 2003: 1). This option has been very popular in Australia, especially in Western Australia, where the area of canola grown increased tenfold between 1996 and 1999[25] and TT varieties now comprise almost all canola (Colton and Potter, 1999: 2; Madin and Bowran, 1999:1; Norton, 2003:4).

The disadvantages of poorer yield and oil content that are associated with "TT" canola are experienced across the board[26], but it has, nonetheless, been

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[24] TT canola was originally bred by a Canadian scientist, Dr Gerhard Rakow in the early 1980s. Using "classical means" (OGTR, 2002b: 23), he produced a substantially resistant line of canola from a cross between canola and a selected, triazine-resistant individual of the *B. rapa* species described as "a mustard weed" (Crabtree, 2006: 1).

[25] Many areas of WA were unsuitable for canola production prior to the availability of TT canola, due to unmanageable Brassicaceous weed problems.

[26] According to the OGTR:

> "Triazine tolerant ("TT") canola has been selected to be tolerant to triazine herbicides (Group C) with the resistance originating from a cytoplasmic mutation. The gene conferring resistance is inherited maternally and, therefore, cannot be spread to neighbouring paddocks by pollen movement. The triazine resistance mechanism also imparts a physiological penalty to the plant

accepted by Australian farmers because of practical advantages that usually compensate for the loss of volume and quality (Colton and Potter, 1999: 2-3). The disadvantageous characteristics of these canolas are a result of their "mode of tolerance" (GRDC, 2004:1) of triazines, which acts through a section of the photosynthetic system (known as Photosystem II, Site A) that is modified in these plants[27] (GRDC, 2004:1; Peterson et al, 2001: 9; Stanley, 2003: 2).

On the basis of its rate of uptake, TT canola translates into a considerable economic advantage for many growers, despite its yield limitations. Compared to conventional varieties, paddock operations are simplified and

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> resulting in reduced fitness. ... Triazine tolerant canola continues to have a yield disadvantage of 10-15% and about 3-5% lower oil content than conventional varieties but is accepted by farmers because it allows canola to be grown where Brassicaceous weeds are a problem". (OGTR 2003b: 105)

This particular line of research and development was abandoned in Canada in the mid-1990s, at the time of the adoption of GM varieties by that country, because of its "20-30% yield penalty" (Crabtree, 2006: 1).

[27] Robert Norton, a leading Australian canola agronomist writes:

> "TT varieties suffer from an inefficient photosynthetic system, which leads to lower vigour and reduced growth, yield and seed oil content. Robertson et al . . identified a 26% lower seed yield for TT canola compared to conventional canola types in weed free situations. Despite this penalty, TT cultivars have enabled growers to use robust in-crop herbicides to control weeds that were intractable in conventional varieties. This technology has been reliable and relatively cheap, which has contributed to its widespread adoption in Australia" (Norton, 2003: 4).

the chemicals are cheap and effective (Norton, 2003: 22). In "the majority of cases" it is sown "because the weeds (particularly Brassicaceae species) present cannot be controlled in the conventional varieties" (OGTR, 2002b: 24), thus allowing "canola to be grown where it could not be considered before" (Colton and Potter, 1999: 2 – 3). As long ago as the late 1990s TT canola represented 90% of Western Australian plantings (where wild radish is a severe and entrenched problem) and 25-30% of those in the eastern states (OGTR, 2002b: 24).

A number of other emerging and potential problems are associated with the use of TT canolas. The OGTR specifies "lower resistance to blackleg and persistance of triazines in the soil" (OGTR, 2002b: 23). It also points out that "parts of Western Australia have a long history of triazine herbicide use ... and [that] there is already evidence of atrazine resistant annual ryegrass ... and triazine resistance in wild radish" (OGTR, 2002b: 23). In 1999, agricultural scientists Madin and Bowran cautioned that "triazine resistance is the most prevalent of all herbicide resistances in the world" (Madin and Bowran, 1999: 4) and that "triazine resistant weeds do loom as a significant problem, ... given the extensive use of triazines in TT canola, lupins, pulse crops and pasture" (Madin and Bowran, 1999: 1).

In addition to several minor risks (such as pollen drift and changes to the weed spectrum) that are almost inevitably attached to the use of herbicide-resistant crops and which may be here considered to be side-issues, Madin and Bowran also cited the carryover of herbicide in the soil and the carryover of resistant canola plants as weeds[28] in subsequent crops in the rotation, as areas of concern with respect to TT canola (Madin and Bowran, 1999: 3).

Perhaps the greatest threat to the long term use of TT canolas, however, is the well-documented tendency for triazines to contaminate the wider environment, including both surface and groundwater (Davies, Cook and Barton, 1994: 209; Hamblin, 2001). This issue, which has led to increasing political criticism and community resistance to their use will very likely lead to some or all of them being either severely restricted or completely banned.

According to research conducted by the Tasmanian Inland Fisheries Commission, triazines:

> ... are noted for their relative persistence and leachability . with half-lives in surface waters ranging up to six to eight months ... Given widespread use of these materials in both agriculture and forestry, it is anticipated that such contamination would be both frequent and widespread. (Davies, Cook and Barton, 1994: 209).

[28] In following pulse (leguminous seed) crops that normally rely on triazines for weed control, these herbicides are, naturally, ineffective for controlling "volunteer" TT canola. Cereal crops, on the other hand, are vulnerable to damage from even slight soil residues of triazines (Stanley, 2003: 3,5). Under some circumstances, it is possible for residual triazine at extremely low levels (the equivalent of 250 ml/ha) to "kill a wheat crop", while barley and oats are even more sensitive to them (Stanley, 2003: 5). While, with foresight and the availability of alternatives, management of these situations is usually possible, it may well be both expensive and inconvenient.

While responsible use of this group of chemicals has not been scientifically shown to pose any serious threat to the soil environment or humans, "they are known to be very toxic to aquatic organisms" (Waugh and Padovan, 2004: 19). According to a Northern Territory Government review of pesticide use and risk to water resources, atrazine is highly soluble, highly mobile and is a high leachate risk, but is only moderately persistent and a moderate runoff risk[29] (Waugh and Padovan, 2004: 19).

The existence of scientific uncertainty about the more serious risks posed by triazine use has led to the persistence of concern and the application of international political pressure. In Australia, the Greens party has actively opposed the ongoing use of triazines in forestry and farming and has conducted a strong campaign against them on the basis of these perceived, if debatable, threats to human health and the environment.

[29] A comprehensive Commonwealth level review of atrazine, initiated in 1995 to investigate a series of serious biosafety concerns, acknowledged the presence of sometimes high residual levels of atrazine in the environment but found no good evidential reason to ban the chemical. Its recommendation in its 2004 "Second Draft Final Review Report", was that: "Active constituent approvals [and] … product registrations are to be affirmed" (APVMA, 2004: 12), while label instructions were amended to extend and strengthen safety precautions.

Irrespective of their merits and dangers, the fate of triazines seems to be sealed[30]. Europe has moved to discontinue the use of atrazine "because it poses an unacceptable risk to ground water" (Marohasy, 2005: 2). According to the CSIRO's *Ecos* magazine, the EU nations, including the UK are phasing triazines out because "they leach rapidly from the rootzone and can contaminate groundwaters and waterways" (O'Neill, 2007b: 20). This action brings the rest of Europe into conformity with the position taken by France, Germany, Italy, Norway and Sweden, which had all banned atrazine by 2002 (Kingsley, 2002).

[30] The detection of triazine residues in waterways and water supplies, sometimes at high levels (APVMA, 2004: 115), has strengthened the public position of those opposed to their use and has forced primary industry and government to adopt a defensive, retreating attitude in response. Tasmanian Greens MHA, Kim Booth and Primary Industry Minister, Steve Kons demonstrated their respective positions during a debate in the Tasmanian House of Assembly in 2005:

> "Mr BOOTH - The Government failed to support the Greens' Chemical Trespass Bill, which was voted down by both Liberal and Labor. If the Chemical Trespass Bill had become an act, it would have in fact prevented the sorts of situations we have now where you have simazine contamination of water supplies such as the Orford drinking water, and atrazine detected in water catchments in various parts of the State. The Minister for Primary Industries and Water is here now, and I will defy him to deny that the oyster kills in Georges Bay were in fact caused by chemical contamination.
>
> Mr Kons – It hasn't been proven. The results … said there was a multiplicity of factors that may have contributed to the deaths.
>
> Mr BOOTH – Well there we are." (Tasmanian Parliament, 2005).

Dr Rob Norton, an agronomist at the University of Melbourne, put the issue in a realistic perspective when he told the ABC's Landline program in 2004 that "Triazines are an outdated herbicide" (ABC, 2004). He pointed out that they had multiple failings and that "In particular, atrazine is identified as an aquatic pollutant" (ABC, 2004). Dr Norton estimated that 600 to 800 tonnes of triazines are applied to canola crops annually in Australia, all of which could potentially be replaced by GM varieties[31] (ABC, 2004).

Australian canola farmers have responded to the economic pressure to remain competitive by almost universally adopting herbicide tolerant varieties.

> During 2005-6, non-GM herbicide-tolerant canola varieties comprised approximately 90-95% of Western Australia's canola crop, with most of this being triazine tolerant varieties. In eastern Australia (SA, Vic and NSW) approximately 80-85% was herbicide tolerant, with 60-70% triazine tolerant and 15% imidazolinone tolerant varieties. (OGTR, 2007b: 47).

Conventional canola is a poor alternative to herbicide resistance but the currently available herbicide resistant options, although economically and environmentally acceptable in the very short term, are likely to become

[31] Although defenders of triazines might reasonably argue that the evidence against them is slim, the potential or hypothetical risks have to be weighed against the palpable benefits and compared with available alternatives. Given the outlined agronomic disadvantages and the frequency with which sometimes very high levels of chemical residues at have been detected in waterways - especially in catchment areas for public water supplies – the continued use of atrazine-tolerant canola would seem a relatively short-term prospect if reasonably safe and affordable alternatives exist.

increasingly unattractive under the twin pressures of biosafety and economics.

GM Canola

If the necessity to reduce chemical and energy inputs and to increase yield and quality outputs is accepted as an ongoing and pressing condition of survival for mainstream canola growers, the development and adoption of GM herbicide resistant canolas are logical steps for the industry to take.

The concern of contemporary agriculture to avoid persistent and dangerous chemicals has both political and environmental advantages. The cotton industry's move to insect resistant varieties has transformed its public image and its practices. The technological change has also delivered productivity gains, as reduced paddock operations translate into reductions in costs and increases in quality control, thus enhancing the industry's ability to compete.

Until the arrival of GM Bt varieties, Australian cotton producers were politically, environmentally, economically and operationally encumbered by the millstone of insect control. In the case of canola production, the pertinent variable cost, which has the capacity to most dramatically impact on industry competitiveness is weed control. Weed control typically accounts for almost 60% of production costs per hectare in conventionally grown canola, according canola farmer and 2005 Nuffield Scholar Andrew Broad (Broad, 2006: 28). It is, consequently, this area of crop economics that over the last 25 years has been identified and targeted by the industry and its researchers as the greatest potential source of productivity gains.

However, productivity gains across the board put downward pressure on prices, so growers selling their product into a commodity market that reflects or represents international prices can only compete and survive if their costs structures are comparable to those comprising the mainstream of production. The very high rates (effectively, industry-wide) of Australian adoption of TT and IT canola, notwithstanding their agronomic disadvantages, reflect the cost burden of weed control in conventional crops and the pressures imposed by the international price of canola as a commodity.

With rare exceptions,[32] Australian farmers are now heavily reliant upon herbicide resistance as a crop trait in order to operate profitably. Alternative markets for non-GM canola, although essential to a GM-free industry, do not appear to exist. A secure and profitable, preferential market for large tonnages of Australian-grown, conventional canola would be reflected in preferential sales, a price premium, and evidence of upward pressure on production. Very clearly, this not the case.

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[32] Such as, situations of low weed pressure, localised soil or environmental limitations or individual grower requirements.

Australian canola growers, typically, are obliged to choose from among the currently available TT and IT seed varieties if they are seeking to minimise crop inputs. Further improvement or refinement of these options would necessarily involve overcoming the disadvantages and limitations that have already been described. These can be summarised as: herbicide purchase/application costs (particularly in the case of IT canola); the compromises of yield and quality inherent to TT canola; the existing and emerging limitations of efficacy of the two groups of herbicides; the problems of ongoing residual activity in the soil where they are applied (both groups) and their movement into and persistence in the wider environment.

Monsanto's *Roundup Ready* and Bayer's *Invigor* herbicide resistant GM canola varietiess address all of these issues with almost complete success. They have been developed and licensed in Australia and involve the use of either of two commonly used broad spectrum, non-residual, post-emergent, herbicides glyphosate and glufosinate-ammonium (usually referred to as "glufosinate"). These chemicals are respectively marketed as *Roundup* and *Liberty*[33].

[33] Bayer separately markets glufosinate as a non-selective herbicides *Basta* and *Finale* for horticultural and more general use. Monsanto has retained the name *Roundup* for all applications.

Probably the most critical advantage that the GM varieties hold over TT and IT canolas is that in contrast to the problems ascribed to the triazines and imidazolinone, the use of these two herbicides does not involve any serious, known, biosafety risk. Both are of low general toxicity and are strongly adsorbed by soil particles, so they tend to remain confined to the location where they are applied. Both are also quite rapidly degraded by soil and water microbes. Glyphosate typically has a soil half-life of 60 days and glufosinate only 7–20 days (Aventis, c2006: 6; Bayer, 2004: 1-2; Hamblin, 2001; Roundup Bulletin, 1995: 5).

Glyphosate and Tolerance

Kansas State University weed scientists Peterson et al (2001: 12) describe glyphosate as having "exceptionally low mammalian toxicity and … minimal pollution concerns because of high adsorption to soil colloids". The Western Australian Water and Rivers Commission recommend glyphosate for use in wetlands, partly on account of its low toxicity (especially to fish) and its limited mobility:

> It is poorly absorbed along the digestive tract and does not bioaccumulate. It has a low toxicity to bees, fish and other aquatic organisms … Glyphosate is strongly adsorbed and inactivated by soil and by organic and mineral suspended particles in water bodies, so leaching and contamination of runoff is negligible. (Taman, 2001: 2).

Glyphosate is an EPSPS (5-enolpyruvyl-shikimate-3-phosphate-synthase) inhibitor, which kills plants by disrupting the biosynthetic function of EPSPS, an enzyme that is essential to aromatic amino acid production (Peterson, 2001: 12; Shaner, 2006: 1-2). EPSPS function is critical to plant growth and it is especially active in meristematic tissue where cell division and differentiation occurs (Peterson, 2001: 12; Shaner, 2006: 1-2). Glyphosate must be translocated from the point of application to the developing root and shoot tips, where growth is occurring, for it to be effective[34].

Two forms of EPSPS exist, one (EPSPS I) that occurs in plants (as well as some other organisms) and is vulnerable to glyphosate, and another (EPSPS II) that occurs in some bacteria and is not vulnerable to glyphosate. Two genes responsible for the synthesis of EPSPS II have been used to produce glyphosate resistance in crop plants such as *Roundup Ready* canola (Shaner, 2006: 1-2). These genes are known as CP4 EPSPS (derived from *Agrobacterium sp.*) and goxv247 (derived from *Ochromobactrum anthropi*) (OGTR, 2001b:1).

Glufosinate and Tolerance

The Northern Territory Government's herbicide review rates Bayer's herbicide, glufosinate, as "low" in respect of runoff and leachate risk as well

[34] Two modes of resistance to glyphosate have emerged in the 11 species of weeds that are known to have developed tolerance to it. One involves changes to the "target site" (EPSPS) of glyphosate and the other causes interference with the uptake and transport of glyphosate within the plant. Both modes of resistance have, so far, proved susceptible to higher rates of herbicide (Shaner, 2006: 2).

as in terms of its mobility and persistence (Waugh and Padovan 2004: 21). It is, however, highly soluble in water and is toxic to fish at moderate levels (50% mortality at or above 14 ppm) (Aventis, c2006: 7). Glufosinate has not been demonstrated to be toxic to bees or earthworms (Aventis, c2006: 7). Peterson et al (2001: 12) of Kansas State University describe glufosinate as having "low mammalian toxicity and minimal pollution concerns because of high adsorption to soil colloids".

The herbicide glufosinate-ammonium is the synthetic form of an amino acid, phosphinothricin, that has been bound to ammonium. Phosphinothricin (PPT) was originally isolated from a substance that was identified in a soil bacterium, *Streptomyces viridochromogenes,* in 1971. In 1976 Hoechst, in Germany, identified its herbicidal qualities and after a long period of development, glufosinate, as the herbicide *Basta* eventually became available in Australia in 1990 (Aventis, c2006: 2).

According to Peterson et al at Kansas State University, glufosinate activity within the target plant:

> … inhibits the activity of the glutamine synthetase enzyme that is necessary for the plant to convert ammonia into other nitrogen compounds Consequently, ammonia accumulates and glutamine levels decrease. Plant damage probably occurs due to the combined effects of ammonia toxicity and deficiency of amino acids required for other metabolic processes. [Glufosinate] has limited translocation[35]. (Peterson et al, 2001: 12).

[35] The limited systemic activity (translocation) of glufosinate within the plant (itself probably caused by plant response to the herbicide) means that it is most effective when applied

Glufosinate resistance in canola (and other crop plants) has been conferred through the insertion into their genomes of the "PAT" and "BAR" genes (Beriault et al, 1999: 619; OGTR, 2003c: 41). The PAT gene and the BAR gene are dominant genes that were respectively (and fairly predictably) sourced from the genomes of *Streptomyces viridochromogenes* and its close relative *Streptomyces hygroscopicus* . The expression of either of these genes triggers production of the enzyme phosphinothricin acetyl transferase (PAT). PAT catalyses the detoxification of PPT and is thus capable of inactivating glufosinate, so when one (or both) of the genes is inserted into a plant's DNA, it will confer resistance to glufosinate. The PAT and BAR genes have both often been used as marker genes (Acre, 2002; Beriault et al, 1999: 619; Nill, 2001).

The two GM canola varietal groups around which the Australian political debate has centred - Monsanto's *Roundup Ready* and Bayer's *InVigor* – although licensed by the OGTR, are still unable to be commercially grown in much of Australia due to the continuation of State and Territory Government

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thoroughly to small weeds and less effective against large, perennial weeds. This limitation also has the advantage, however, of rendering it a relatively safe herbicide to use around larger established crop plants such as fruit trees and generally reduces the risks associated with drift (Aventis, c2006: 5; Beriault et al, 1999: 619). In the normal course of events this characteristic would not compromise its effectiveness in the cultivation of herbicide resistant annual crops, where large or perennial weeds ought not be present.

bans[36]. Both, through the use of softer herbicides, surpass the agronomic and biosafety advantages of TT and IT canola, and can reasonably be expected to deliver significantly superior economic outcomes for growers[37].

[36] Victoria and NSW did not renew their moratoriums against these varieties when they expired in February 2008. They continue to be banned in all other States except Queensland.

[37] These varieties have been the subject of extensive trials and scrutiny and in biotechnological terms are the exact equivalents of herbicide resistant GM cotton varieties that have been grown legally in Australia for a number of years. For example, the first generation of *Roundup Ready* cotton (legal) and canola (banned) were both modified with the CP4 EPSPS gene, while the various herbicide tolerant lines of *Liberty Link* cotton (legal) and *In Vigor* canola (banned) are all modified with the BAR gene and/or the PAT gene (OGTR, 2001: 1; OGTR, 2002c: 1; OGTR, 2003, 1-6; OGTR, 2003c: 15; OGTR, 2005: 1).